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Analysis of Cooperative Skills Development through Relational Coordination in a Gamified Online Learning Environment

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Abstract: One of the main problems of the sudden digital transition to online education due to the COVID-19 pandemic is the increased isolation of students. On the other hand, one of the main goals of higher education is to develop students' cooperative competence. This experimental study presents an online learning environment, consisting of a set of web-based resources such as virtual laboratories, interactive activities, educational videos and a game-based learning methodology. The study also examines the influence of the combination of such resources with active and collaborative learning on the improvement of students' relationships and the development of cooperative competence. To this end, an analysis was conducted based on the data collected from a core subject of the Computer Engineering and Computer Science Engineering degree courses. The answers of an online survey (n = 289) were examined by using the structural equation modeling technique (SEM). The results suggest that the proposed learning environment has a significant and positive impact on the two dimensions of relational coordination; communication and relationships, and plays a key role in the acquisition and development of cooperative competence. Findings also indicate that effective, accurate, frequent and timely communication, positively influences on students' relationships. Additionally, this study addresses other important issues with significant theoretical and practical implications for higher education.

Keywords: collaborative learning; cooperative competence; virtual learning; educational technology; game-based learning; relational coordination

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1. Introduction

The integration of technology in educational systems has been a key driver to enhance teaching and learning for many years. However, it has been in the COVID-19 situation that the use of technology and online learning has grown exponentially, highlighting the countless opportunities and advantages it can offer, but also emphasizing some deficiencies and limitations. One of the main problems of online learning is the feeling of social isolation of the learner [1], which is the reason of many failures and dropouts. According to [2] the feeling of connectedness and the perception of belonging to a community is crucial for learners.

Aligned with that sense of inclusion, companies are increasingly proclaiming the importance of strong communication and cooperation skills among professionals. The computing professional no longer fits the old stereotype of an isolated computer programmer working alone; instead, most computer jobs require professionals to interact and cooperate with others.

For these reasons, one of the main goals of higher education is to develop students' collaborative or cooperative ability. Consequently, many institutions promote the integration of collaborative learning strategies. In this line, the European Higher Education Area (EHEA) and Bologna process urged European higher education institutions to redefine their degree programs on competency-based achievements that better prepare graduates for their future role in society [3]. However, although the acquisition and development of these essential competences is highly demanded nowadays and so important that they are described in degree programs and teaching guides, there are no clear guidelines on how to improve these skills in addition to knowledge. Technology and appropriate instructional strategies can play a key role in addressing this problem [4,5]. Therefore, by combining learning strategies and technology resources, it is possible to create meaningful learning scenarios that increase communicative and collaborative skills and also improve in-depth learning.

In order to increase students' motivation, encourage participation and improve the learning process, we have created an online learning environment (OLE) from scratch, which integrates interactive exercises, virtual laboratories video teaching and game-based learning [6,7]. The use of this OLE has been crucial to increase students' interaction and involvement and to allow active and collaborative learning methods in the classroom. This increase in participation and interactions has had an impact on enhancing student relationships [7] which is more necessary that ever, especially due to the COVID-19 pandemic.

The main goal of this study is to analyze the effect of this web-based online learning environment. To achieve this, we make contributions in three aspects. Firstly, by evaluating whether the online learning environment has had a significant impact on students' relationships. Secondly, by analyzing whether the learning environment has led to a significant impact on cooperative competence acquisition. Thirdly, by studying the impact of relational coordination on students' cooperative competence.

This paper is structured as follows: Section 2 contains a literature review and the theoretical framework. This section explains what the online learning environment consists of and what it is based on, as well as the learning methodology used which has been facilitated by the online learning environment. Section 3 presents the model and its components; also in this section the hypotheses are presented. Section 4 describes the research methodology, the instrument employed, the participants, and data collection, while the data analysis and results are presented in Section 5. A discussion follows in Section 6. Finally, the paper ends with the conclusions drawn from the study.

2. Literature Review and Theoretical Framework

During the global pandemic sparked by COVID-19, the educational system has experienced a radical shift and online learning tools have become more essential than ever before. This shift is a great opportunity for universities to better adapt and enrich their educational practices by means of innovative learning technologies [8]. The advantages offered by online learning and technological learning tools have been extensively studied and documented over recent years; for example, to enhance learning accessibility and flexibility [9,10], improve students' achievement [6,11], and give highlighted support for learning in practice and experimentation [8,12] and for active learning approaches [13]. However, despite the numerous studies on the use of technology in education, there are limited studies to evaluate the impact of relationships and the acquisition of competences in active, participative and collaborative learning environments. Hence, this study addresses this gap in the literature by applying and testing a model to gain insights into the impact of an online learning tool and an active and collaborative environment on the improvement of relationships and the development of cooperative competence.

2.1. Active Learning

In an increasingly digitized society, the mere transmission of information no longer constitutes efficient teaching, so the traditional classroom learning process does not seem to be the most suitable learning model to achieve the new challenges facing higher education.

Active learning is a range of teaching strategies that focus on the effective participation and involvement of learners. Thus, in active learning, the main responsibility for learning shifts from the teacher to the learner, who takes on a central role. According to Prince [14] to put active learning into practice, students need to participate in meaningful learning activities and reflect on what they are doing.

There is empirical evidence that proves the benefits and the effectiveness of active learning compared to traditional lecturing [14,15]. Active learning involves students in the learning process, adapts to the learner's style and provides spatial and temporal flexibility [16]. In addition, active learning promotes the acquisition and development of key competences [17,18].

In line with [13], technology is fundamental to support the implementation of active methodologies inside and outside the classroom. Thus, thanks to pre-study using online learning tools, class time can be spent using cooperative and participative learning strategies which can also be supported by technology. Teachers can foster active learning, propose challenges and collaborative projects for developing students' skills, and get students to feel more involved with their own learning.

In a study analyzing the different types of active methodology, ref [19] found six main types of active methodology, namely: Flipped classroom, Game-based learning, Problem-Based Learning, Project-Based Learning, Peer instruction, and Team-Based Learning. The last four would fall under collaborative learning.

Flipped classroom [20] is probably the best known and most widely implemented active learning methodology, which is why the two terms are sometimes used interchangeably. In this approach, teachers provide students with learning resources, usually video lessons; the students can work, watch or listen at home at their own pace. Later, in the classroom, students have time to apply acquired knowledge, and collaborative and participative activities can be carried out.

Below we discuss collaborative learning and game-based learning.

2.2. Collaborative Learning

The abrupt adoption of virtual learning tools and e-learning experimented with in face to face universities due to the COVID-19 pandemic has been a great challenge for many students and lecturers. Although students have a high level of training and ease of adaptation to technological tools, this has been particularly difficult because of the feeling of social isolation. On the other hand, cognitive development depends to a large extent on social interaction and collaboration with other people. Thus, according to [21], collaborative learning is the educational use of small groups of students to work together in order to maximize their own and others' learning in a well-defined period of time. Similarly, ref [22] defines collaborative learning as an instructional approach in which a small number of learners interact together and share their knowledge and skills in order to reach a specific learning goal.

Collaborative learning structures allow more interaction and dialogue among learners and help to create a feeling of connectedness and belonging among learners, which, according to [2], is crucial for learners. This perception of belonging to a group, a team, or a community avoids the perception of isolation of learners, increasing enthusiasm and motivation and decreasing failure and drop-out rates.

Collaborative learning can be an effective teaching method in both traditional and online learning environments, and may be organized in a wide variety of ways, including as a means to complement more traditional activities. It can also be useful with quite a wide range of students.

Different experiences applying collaborative methodologies have produced successful results showing numerous benefits, including increasing knowledge retention [23], enhancing creativity [24], helping to prepare students professionally [25], enhancing results in terms of competences acquired compared to other teaching methods [26], or improving students' theoretical and practical ability, cooperative ability and autonomous learning ability [27].

Although collaborative learning has been seen as a difficult pedagogical strategy, in agreement with [28], technology can make online collaborative learning more effective and ubiquitous.

2.3. Game-Based Learning

Higher education institutions have a growing interest in recent years in harnessing the potential of game-based learning for integration into both traditional learning and e-learning, and as a complement to both active and collaborative learning.

Game-based learning is defined as the use of game elements in non-game contexts to promote participation and engagement [29]. Including this strategy in education attracts students and helps them pay attention to their studies plus challenges and involves them in an active learning process. Game elements such as badges, content unlocking, avatars, collections, gifting, level progressions, quests, social graphs, and virtual goods are used in learning activities to achieve educational objectives [30].

Several authors have investigated the positive effect of games to motivate and engage students [31,32], and to improve performance and results in practical work [33]. It also develops their experience in terms of students' learning attitudes, interest in learning, and acceptance of technology [34].

An increase in students' engagement results in improved learning. Furthermore, according to [31], increased engagement also means increased cooperative competence.

In addition, exceptional situations such as those experienced with the COVID-19 pandemic require creative and critical thinking to find new answers and solutions. Incorporating elements such as participation or competition motivates students and creates engaging learning environments that help students to continue their studies. Thus, game-based learning has been widely used to enhance the learning process in different environments since the emergence of COVID-19.

2.4. Virtual Learning Tools

According to Adel and Dayan [35] virtual learning is the concept of digitalizing learning material and placing it online, so both students and instructors can manage the educational process effectively. The use of virtual learning tools provides new opportunities and a wide range of benefits to improve the learning process that have been widely studied and documented; for example, increase students' motivation [36], provide autonomy, flexibility and accessibility to the learning contents enabling study from anywhere [9,10], develop students' autonomous learning ability [37], increase the efficiency of teaching and improve students' achievement [4,11], acquire and develop competences [5,38] and support active learning approach [13]. Furthermore, virtual learning could bring other important benefits, such as eliminating unnecessary travel, saving costs and waste of time and also providing other indirect benefits such as the decentralization of urban centers or environmental improvement.

However, especially with the global pandemic sparked by COVID-19, virtual learning has become unquestionably indispensable. Universities around the world have converted all or part of their activities to an online mode to ensure the safety of students and lecturers, and all the work that has been conducted should be useful for the future. According to several experts, the influence of COVID-19 will impact higher education for much longer after the epidemic has been finally controlled [39]. Therefore, it is foreseeable that the increase in the use of e-learning and virtual learning tools will be very notable in the future. In this line, ref [40] affirm that finding the right balance between online and on-site will be the real strategic challenge for the universities in the future. Other authors, e.g., ref [10], also argue that it will be necessary to develop a blended approach to education that flexibly combines virtual and face-to-face learning. Thus, this emergency caused by COVID-19 could be an opportunity for education to accelerate the adoption of other forms of learning supported by virtual learning tools.

The technological development and wide availability of virtual learning tools have made the adoption of online learning relatively easy. However, the real challenge for universities today is to integrate and combine these tools with an effective learning approach and to also consider the need for hands-on experience as well as skills development [41].

Many examples of recent research show that the combination of virtual tools and real components employed collaboratively has proven to be a success, especially in times of COVID-19. For example, Adel and Dayan [35] propose a blended learning model where digital technology is utilized to virtually engage students. The blended learning model proposed integrates managed virtual support and traditional learning environments, and includes a web server that hosts all applications and tasks and provides a virtual platform that simulates real labs. Additionally, Loukatos et al. [8] highlight educational activities for agricultural engineers that challenge them to use problem solving techniques and team collaboration skills through a blended learning activity by means of a robotic arm platform to assist the students to tackle the lack of physical presence in the classroom due to COVID-19. Similarly, Smigelski, Movassaghi and Smal [42] describe the impact of the COVID-19 pandemic on urology trainees, with a focus on virtual learning initiatives. Smigelski, Movassaghi and Smal [42] conclude that despite the undeniable devastation of COVID-19, some good things may be found in the innovative solutions that have arisen in education.

COVID-19 has accelerated the use of virtual learning tools, and everything learned and all educational resources developed during this time of the pandemic will have a lasting effect on education and continue to be useful in the years to come. Universities should combine these virtual learning tools with learning methods of collaboration and participation that engage students and foster efficient learning, experience, communication, and competence development inside and outside the classroom.

2.5. Learning by Doing and Hands on Activities

Learning activities with hands-on exercises in which students play an active role engage and motivate them more effectively than learning activities where they are passive.

Learning by doing is essential in scientific and technological fields such as engineering, which involve laboratory practical work in addition to theoretical lectures, and where students' hands-on exercises and laboratory work form crucial aspects of their learning. In these fields, virtual laboratories, simulators, and interactive tools are essential to provide students with virtual practical work [41].

Several authors have suggested that a successful strategy for developing practical learning activities is the creation of web-based simulators and virtual laboratories. Some examples include a virtual electrical machine laboratory for electrical engineering courses [43], a remote laboratory applied to control engineering learning [44], or a laboratory framework for a Networked Control System design to provide plug-in free online experiments [45].

There are many advantages of such simulators and virtual laboratories designed for practical activities. Thus, ref [46] found that students using a virtual laboratory acquire a better conceptual understanding and develop better procedural skills than students using a traditional laboratory. Likewise, ref [47] suggested that learning outcomes are equal or even better using virtual or remote versus traditional laboratories. In a similar study, ref [45] verified the pedagogical effectiveness of their virtual control system against a physical one. Additionally, ref [48] claim that a virtual interactive laboratory in engineering mathematics enhances students' learning.

In addition to all of the above, face-to-face labs are expensive, both because of the instruments used and because the groups of students have to be reduced; therefore, according to [49], virtual labs also provide remarkable cost advantages.

2.6. Teaching Videos

According to [50], video is one of the educational technology resources more widely used and with greater potential. The results of many studies find videos to be an effective and successful learning tool that reported significant knowledge gains [51], grade improvement and student satisfaction [52], or higher practical skills acquired [53].

Videos are used in a wide variety of ways; e.g., the massive, online, and open courses (MOOC), the infinite number of courses and tutorials that can be found on YouTube, and other alternatives such as Vimeo, Yahoo Video, Viddler, or Screencast. Some are expressly created for educational purposes, such as School Tube, Teacher Tube or Teacher TV and, of course, videos are used in distance education, but also as the linchpin in hybrid education environments as an effective tool of autonomous learning.

There is no doubt that teaching videos are extraordinarily useful as learning support, especially in a pandemic situation such as COVID-19; nevertheless, media such as video are not effective on their own—according to [54], they must be embedded in appropriate instructional contexts to bring out their full educational potential.

2.7. Online Learning Environment (OLE)

Following previous research, both in the search for effective virtual learning tools and in the search for the most appropriate learning approaches to apply them, an online learning environment (OLE) integrating web-based resources was developed [6].

The OLE is based on appropriate instructional strategies, learned over several years of teaching. Taking into account the main needs and deficiencies of the students, through tests, evaluations and based on feedback from students and teachers, the application has been improved year after year.

The platform integrates a range of randomly generated interactive and graphical activities such as computer simulation, virtual laboratories or explanatory teaching videos with exercises to evaluate understanding. The activities in OLE cover the contents of the subject Fundamentals of Computer Technology. from exercises with different numbering systems, truth tables, circuit simplification exercises, Karnaugh maps (min terms, and max terms) of different numbers of variables, combinational circuit simulation exercises, circuit analysis and synthesis, logic gate and integrated circuit exercises, sequential circuits, bistables truth and transition tables, counters, graphs of finite-state machines to memory system activities, operations with address, data, and control buses, to a simulator of an EPROM memory recorder.

The OLE also includes game-based learning that aims to encourage learners to work with the application. Learners can choose the type of activity, watch videos, or see their performance and the badges earned, encouraging a level of competence that stimulates learners. The purpose of the badges is to increase student motivation, since, according to [55], this is a primary component that positively affects learning.

In previous studies [6], we evaluated and confirmed the effectiveness of OLE in motivating students, increasing learner satisfaction, as well as improving the learning process and learning outcomes.

One of the most useful options of OLE is to be used as a self-study tool. With the time saved with this previous study, active learning activities can be carried out. Thus, teachers can devote more time to student diversity and students have more time for problem solving.

Furthermore, OLE allows activities to be carried out from any mobile device, which has made it easier to carry out individual and group activities in the classroom.

In addition, OLE has been helpful as an assessment tool, as students' successes or failures can be registered. This reduces the risk of impersonation or cheating as the exercises are randomly generated.

However, also in the situation experienced due to the COVID-19 pandemic, OLE has proved to be a useful and efficient tool to use in online classes, to maintain interest and to make lessons more dynamic, which is really very necessary in synchronous lessons of two or more hours.

Figure 1 shows some examples of interactives exercises that are randomly generated. Although students can attempt an unlimited number of exercises, they have only three opportunities to solve each activity before the correct result is displayed, another activity is randomly generated, and the sequence begins.

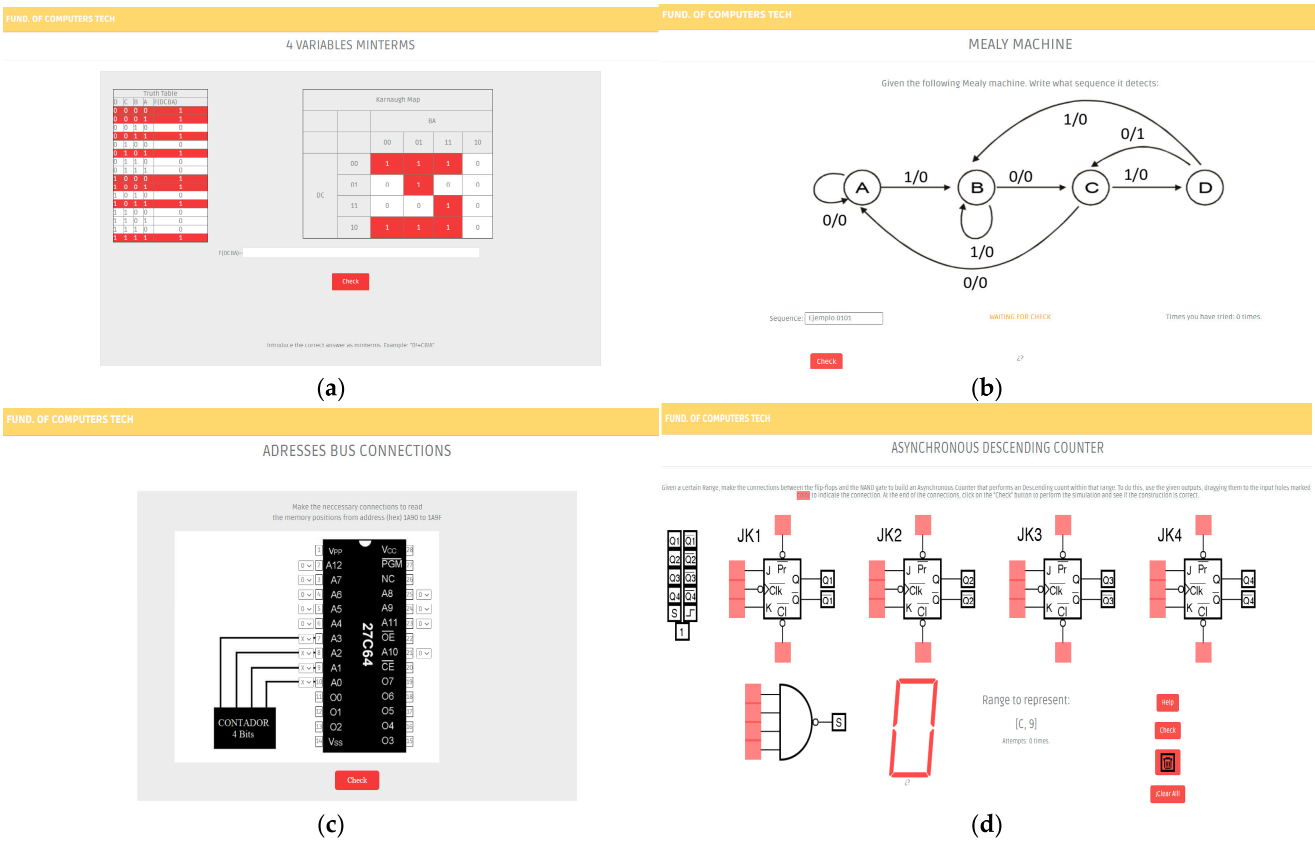

Figure 1. Example of OLE interactive activities randomly generated. (**a**) Karnaugh Maps, min terms, (**b**) example of sequential circuit: asynchronous counter with JK bistables, (**c**) example of memory system circuit: addresses bus connections, and (**d**) example of finite state machine graph: Mealy.

3. Research Model and Hypotheses

Based on the previous research, a theoretical model was developed to evaluate the impact of the OLE on students' relationship and on cooperative competence acquisition and also to understand the influence of relational coordination on cooperative development.

Each of the hypotheses presented below correspond to each path in the SEM and forms part of the aforementioned objective.

3.1. The Learning Environment (LE)

Just as active learning is supported by technology [13], technological resources do not provide a learning solution by themselves [56]. Hence, combining the OLE resources with Learning Methodologies (LM) such as active and collaborative learning strategies in the Learning Environment (LE) has been created to increase classroom interaction and encourage participative and cooperative work. Communication and interaction is achieved through questions and answers between teacher and students. Similarly, cooperative work is reached when two or more students learn or attempt to learn something together, for example by using problem solving, discussion and agreement. These types of activities are essential for students, especially in the first year of university [57], not only due to the connection to like-minded or same-age peers but also to obtain social and academic integration and achievement. In addition, student involvement is increased with challenges and discussions, which enhances student learning in a cognitive and affective way.

By means of the previous autonomous study, OLE supports active learning. Thus, participatory and collaborative activities using game-based learning have been employed, e.g., using mobile-based learning applications that allow activities for rapid development, with immediate visible results such as Socrative, Kahoot or Mentimeter that are easy, intuitive applications that perfectly match the stage of class attendance.

On the other hand, as suggested by [58], is essential to provide online or virtual learners with multiple channels, both synchronous and asynchronous, in order to accommodate their preferences for different communication styles. Therefore, OLE has been used not only to motivate and involve students in synchronous classes, but also for students to do individual and collaborative activities asynchronously. An example of collaborative activity implemented is the jigsaw method [59]. Each member of a group takes responsibility for a piece of content and then shares it with the other participants to create a possible final joint representation. However, there are many possible variations of this methodology, as many as we can imagine.

In view of the above, we hypothesized that the LE created through the combination of the OLE resources and the active learning methodologies would have a positive impact on communication (H1) and on student's relationships (H2), and also that this LE would be a significant factor that positively influenced cooperative competence development (H3).

3.2. The Relational Coordination Model

The model of relational coordination (RC) has proved to be a power driver for quality and efficiency outcomes. Relational coordination model [60] emphasizes the need to understand the coordination in relationships and the dynamic of communication at organizations to reach best organizational results. So, different research has applied the RC model in different sectors such as airlines, healthcare, cloud computing, or education.

In the field of health services, the effect of relational coordination on the nurses' job satisfaction and on the quality of life of nursing homes residents was evaluated, and the results indicated that there was a positive relationship between the level of relational coordination and both results [61].

In addition, ref [62] analyzed a case of a medical service for the organ donation and transplantation process. The results showed that service interaction emerges as the atomic unit of productivity analysis, since it is significant at the process level and exhibits a strong cause–effect relationship, where service interactions identify who is responsible for what in complex services.

The relational coordination model has also been studied in other areas such as education, thus [63] indicated that ICTs are tools that facilitate the online educational framework and that have been extended to practically all business areas.

On the other hand, ref [64] analyzed the application of relational coordination in three Public Universities, the Rey Juan Carlos University (URJC), the Complutense University (UCM) and the Carlos III University (UC3M). The results showed that UC3M presents higher percentages of relational coordination, since it has a strategic plan focused on good coordination.

Besides, ref [65] observed that the communication channel has an impact on the frequency of communication and that quality relationships increase the degree of teacher satisfaction with their work and also increase the degree of satisfaction with the learning management system, and thus improve student satisfaction.

Relational coordination was also applied to some online courses given in Spanish universities and private companies, and it was found that organizations obtain better results in terms of satisfaction by providing shared knowledge, shared goals and mechanisms of mutual respect [66].

Therefore, according to the previous research, quality relationships and quality communication increase teacher and student satisfaction by providing shared knowledge, shared goals and mechanisms of mutual respect, supported by frequent, timely and problem-solving communication, leading to better results. Despite this, there is a lack of literature exploring the impact of relationships and communication on learning environments and competence development.

According to the RC model, the coordination process takes place through a network of relationship and communication dimensions. Gittel [61] indicated the RC model is relatively unique and includes relational coordination dimensions: Relationships and Communication.

Relationships are based on the relational dimensions included in the model as a shared goal, shared knowledge and mutual respect. They enable students and lecturers to coordinate more effectively the work processes they are involved in [60,66]. These relational ties are mutually reinforced through communication links that allow effective coordination of work.

Communication is based on the communication dimensions included in the model such as frequency, timeliness, accuracy and resolving problems. Thus, accurate information makes it easier for teachers and students to teach, learn, help and share at the same time. In addition, frequent and timely communication means that students do not have to wait long time to receive information from teachers, which would create uncertainty about their learning tasks [67].

Based on the previous studies, we hypothesized that communication positively influenced acquisition and development of cooperative competence (H4) and, on the other hand, communication would positively impact relationships (H5). In turn, it seems logical to assume that good and fluid relationships positively influence cooperative competence improvement (H6).

3.3. Cooperative Competence

Universities are often criticized for being disconnected from the world of work. Thus, while companies are increasingly looking for professionals with communication and cooperative competences, leadership and teamwork skills, many universities continue to use the same old teaching methodology, focused only on learning content.

According to [68], competence-based education helps to bridge the gap between university and companies' requirements.

Cooperative competence can be defined as the ability of working with others effectively. It means the capacity to exchange information and to establish, develop and maintain social relationships. Along with communication competence comes social skills. Cooperative competence includes interpersonal skills, critical and self-critical capacities, the ability to communicate with others and the ability to work in a team.

Social skills in general and cooperative competence in particular are undoubtedly key for higher education. Hence, it is necessary to develop tools and to implement efficient learning methodologies that help in the development of these competences. Regarding tools for the development of cooperative competence, following [5], online learning environment have proven to be very successful to promote the students' acquisition of competences as well as social skills. As for the appropriate methodology, some authors such as Schaeper [18] claim that active learning environments enhance the acquisition of social competences (cooperative and communicative).

That is why, based on the interactive and collaborative activities and learner involvement offered by the online learning environment and the relationships that are created in the active and collaborative learning approach, our study suggests that this learning scenario enhances cooperative competence.

The conceptual framework of this research model and its different elements can be seen in Figure 2.

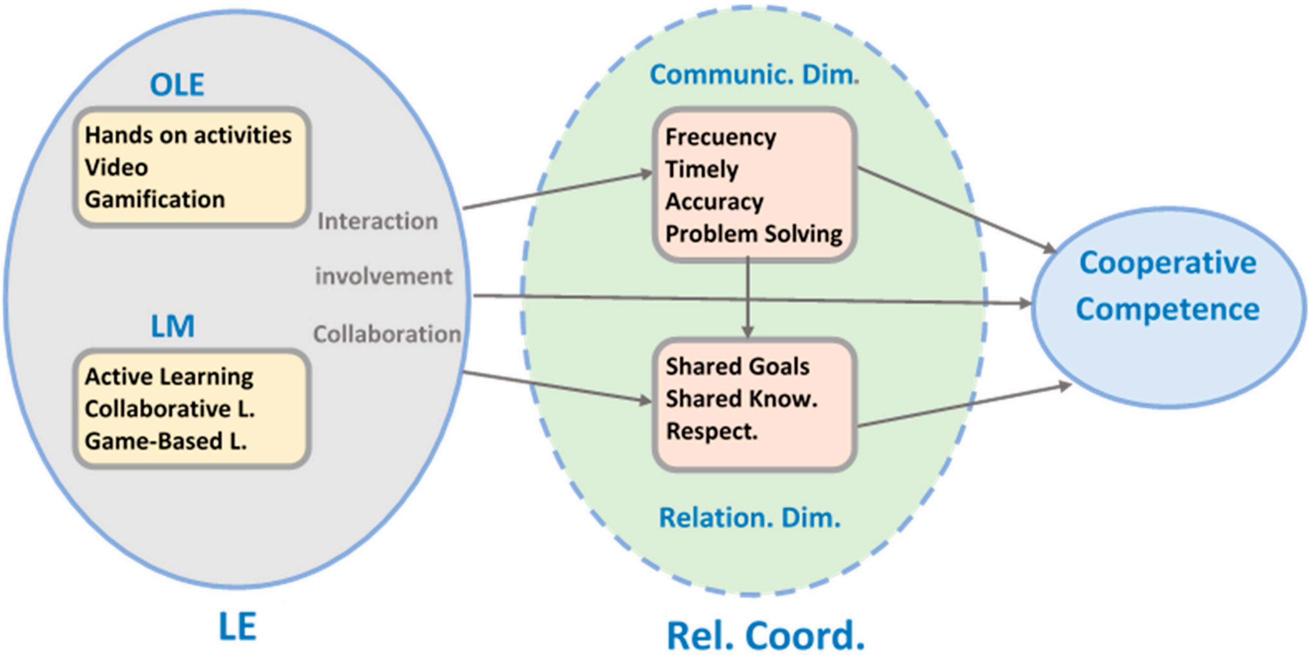

Figure 2. Conceptual research framework.

4. Research Method

Based on other reviewed and validated models and following several criteria as guidelines [69], an online questionnaire was designed to test the hypotheses.

4.1. Participants and Data Collection

Data were collected from students by means of voluntary and confidential online questionnaires. The full sample consisted of 289 students (253 males and 36 females) aged mostly from 18 to 20 years old. These students were taking the course Fundamentals of Computer Technology, a core subject in the first year of the Computer Engineering and Computer Science degrees at the University of Alcalá, Spain.

The main objective of the subject Fundamentals of Computer Technology is to understand the functioning of a computer at different levels of abstraction, from logic gates to basic electronic devices, combinational and sequential circuits, with an introduction to functional units at the architecture level.

There was a first survey conducted at the beginning of the course, and its purpose was simply to determine the initial knowledge of students and their willingness to use OLE tools (virtual interactive exercises, teaching videos, gamification) and active learning activities (active learning, mobile-app activities, gamification). In this questionnaire, students were asked if they had ever used it, what their experience was and what their expectations were about the efficiency of each of the LE tools.

The answers from this initial questionnaire were contrasted with the answers to the same questions at the end of the course. In this questionnaire, other questions to determine the degree of satisfaction with the OLE tools were included. These questions are based on a validated questionnaire used by other investigators [33,36].

Nevertheless, the central survey of this study aimed to analyze the research model (Figure 2) and to evaluate the hypotheses presented. This questionnaire was conducted upon completion of the course and is addressed in the following section.

4.2. Instrument

Questionnaires are highly accurate and widely used for all types of research, including those related to learning and competence acquisition [70,71]. The questionnaire follows a 5-point Likert bipolar scale [72], with answers ranging from 1 “strongly disagree” to 5 "strongly agree", adopting the usual method for measuring variables that are not directly quantifiable [73].

Items for each variable were adapted from scales that have been validated in previous studies. Hence, the LE construct use collaboration, involvement and interaction. Questions on Interaction, and Collaboration were adapted from the Distance Education Learning Environments Surveys (DELES) [74]. This instrument assesses students' perceptions of virtual learning environments and has been used in numerous studies with strong reliability and validity [75,76]. Questions on involvement were based on the classroom environment instrument: What is happening in this class? (WIHIC) [77], that examine students' perceptions of the classroom by combining some relevant scales from existing questionnaires and is validated in several studies [78–80]. Questions on relational coordination are based on an adaptation of the original questionnaire provided by Gitell [61]. It has also been adapted by [63,64,81] in previous research applied to education. Items to evaluate cooperative competence follow the "Evaluation in Higher Education: Self-Assessed Competences" (HEsaCom) [70,71].

The questionnaires used simple questions and easily understood language to minimize errors in items related to variance. No research intentions or hypotheses were mentioned, items were clearly formulated, abstract questions or terms were avoided, and there were no double-barreled items. Several experts revised the questionnaires to determine whether the questions were appropriate, unambiguous and easy to understand; a few modifications were made following the feedback.

5. Data Analysis

Data have been processed by using SmartPLS 3.2.6, through the PLS multivariate technique based on structural equation modeling to visually examine the relationships between unobservable or latent variables, such as those conveyed in the hypotheses [73]. PLS does not require any parametric conditions and is recommended for small samples [82] due to is predictive accuracy, which means that the model could be replicated in other scenarios [83].

5.1. Justification of Sample Size

The sample size issue is one of the main features of PLS [84] (p. 198). The segmentation process used by the PLS algorithm renders divide complex models into subsets in order to calculate sample size based on the highest number of structural paths directed at a particular dependent latent variable. According to [85], increasing sample size to 100 is recommended in order to reach acceptable levels of statistical power. Roldán and Cepeda [86] proposed specifying the size effect for each regression while consulting the power tables developed by Cohen [87] to obtain a more precise assessment.

Instead of using the old heuristic rule of 10 cases per predictor proposed by Barclay, Higgins and Thompson [88], Hair et al. [89] suggested using programs such as G*Power or G*Power 3.0 for a specific power analysis according to model specifications [90,91].

The expected effect size (ES) and the significant alpha (α) and power (β) values were used to calculate the minimum necessary sample size. For this purpose, a multiple regression study was conducted with four predictors, an average effect size (ES) of 0.15, an alpha of 0.05, and a power of 0.95, in accordance with Cohen [87]. In this case, the minimum sample result was N = 129 participants. Since the study sample was comprised of 289 valid cases, the sample comfortably exceeded all criteria for the analysis by using the structural equation modeling technique.

5.2. Measurement Model Evaluation

According to Carmines and Zeller [92], individual reliability should be analyzed at the beginning of the process of ascertaining the proper indicators. As shown in Table 1, loads (λ) were greater than 0.707, indicating that individual item reliability was acceptable [92].

Table 1. Outer model loadings.

	Coop-Comp	Comunic.	LE	Relations
c-coo-1	0.822			
c-coo-2	0.800			
c-coo-3	0.880			
c-coo-4	0.798			
Com-1		0.788		
Com-2		0.767		
Exa-2		0.707		
Frec-1		0.782		
Rsp-2		0.721		
int-1			0.843	
int-2			0.866	
int-3			0.816	
inv-1			0.851	
collab-1			0.862	
collab-2			0.898	
collab-3			0.844	
Con-1				0.842
Obj-1				0.816
Res-1				0.830
Res-2				0.710

Cronbach's alpha and rho A test values are above 0.7 [93]. The effectiveness of each construct was also validated using the composite reliability (CR); each value was also above the level of acceptance of 0.7 in all the cases [94]. Convergent validity is assessed via the average variance extracted (AVE). AVE values should be greater than 0.50 [95]. Consistent with this suggestion, AVE measures for all variables exceed 0.568 (Table 2).

Table 2. Reliability and validity of the constructs and criterion by Fornell–Larcker.

	Cronbach's Alpha	rho_A	CR	AVE	Fornell-Larcker Criterion			
					Coop-Comp	Comunic.	LE	Relations
Coop-comp.	0.845	0.852	0.895	0.682	0.826			
Communic.	0.817	0.833	0.868	0.568	0.625	0.754		
LE	0.938	0.939	0.950	0.730	0.765	0.689	0.855	
Relations	0.815	0.833	0.877	0.642	0.562	0.703	0.588	0.801

In accordance with Fornell and Larcker [95], the discriminant validity was analyzed through the comparison between the square root of each AVE on the diagonal and the correlation coefficients. As shown in Table 2, The values of the diagonal were higher than rows and columns, indicating acceptable discriminant validity of the measurements.

In addition, the Heterotrait–Monotrait method (HTMT) was also applied [96]. The values obtained should be less than 0.90, although a value higher than 0.85 [96] should be interpreted as a weak correlation between constructs. Table 3 shows that the HTMT ratio was valid because to their values were all less than 0.85. In our case, this requirement was fulfilled.

Table 3. Discriminant validity matrix (HTMT), R^2 y Q^2 results.

	Coop-Comp	Comunic.	LE	Relations	R^2	Q^2
Coop-comp.					0.610	0.396
Communic.	0.710				0.475	0.251
LE	0.846	0.754				
Relations	0.657	0.813	0.659		0.514	0.317

5.3. Structural Model Analysis

In response to the literature reviewed, a research model (Figure 3) was developed to investigate the influence of the proposed learning environment on the improvement of students' relationships and the development of cooperative competence.

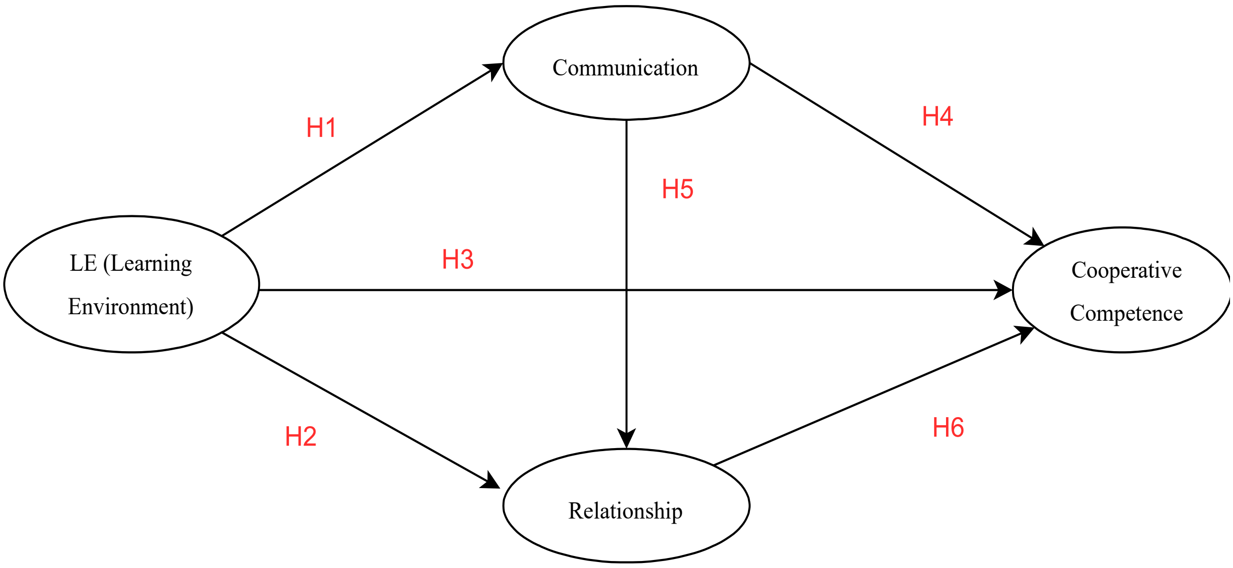

Figure 3. Structural model (baseline model).

The PLS program can generate t statistics for significance testing of both the inner and outer model, using the procedure called bootstrapping [97]. In this procedure, a large number of subsamples (5000) are taken from the original sample with replacement to give bootstrap standard errors, which in turn give approximate T-values for significance testing of the structural path.

The results of the bootstrapping procedure were as follows:

Coefficient of determination (R^2) defines the prediction of the model. It means the amount of variance explained by the construct within the model. R^2 is strong, moderate, and weak when the values are higher than 0.67, 0.33, and 0.19, respectively [98].

Table 4 shows the variance explained (R^2). The model explained 61% of the total variance.

Table 4. Structural model results.

	R^2	Sample Mean (SM)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	*p*-Values	Q^2
Coop-comp.	0.610	0.616	0.042	14.590	0.000	0.396
Communic.	0.475	0.476	0.050	9.458	0.000	0.251
Relations	0.514	0.518	0.055	9.376	0.000	0.317

On the other hand, the predictive relevance (Q^2) is calculated for the Stone–Geisser test [99] and for the latent variables that predict "cross-validated redundancy" [97]. There is a relevance prediction in the cases where $Q^2 > 0$. Table 4 shows that all the constructs Coop-comp, Communic, and Relations fulfil this requirement.

Standardized regression coefficients show estimates of structural model relationships, that is, the hypothesized relationships between constructs. Hence, the algebraic sign is analyzed if there is a change in sign; the magnitude and statistical significance (T statistics) was greater by 1.64 (t (4999), one-tailed test). Next, the hypotheses were checked and validated, and the relationships were positive, mostly with high significance, as shown in Table 5.

Table 5. Structural model results. Path significance using percentile bootstrap 95% confidence interval (n = 5000 subsamples).

Hyp.	Results	Influence	SPC	Sample Mean (SM)	Standard Deviation (STDEV)	T Statistics |O/STDEV|	p-Values	± Change
H4	Accepted (*)	Communic → Coop-comp	0.122	0.121	0.069	1.768	0.039	No
H5	Accepted (***)	Communic → Relations	0.567	0.567	0.056	10.128	0.000	No
H3	Accepted (***)	LE → Coop-comp	0.612	0.612	0.055	11.144	0.000	No
H1	Accepted (***)	LE → Communic	0.689	0.689	0.037	18.769	0.000	No
H2	Accepted (**)	LE → Relations	0.197	0.198	0.063	3.154	0.001	No
H6	Accepted (*)	Relations → Coop-comp	0.116	0.119	0.066	1.752	0.040	No

Note: t (0.05, 4999) = 1.645158499, t (4999, 0.01) = 2.327094067, t (0.001, 4999) = 3.091863446, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ns. No significant based on t (4999), one-tailed test.

When a percentile bootstrap was applied to generate a 95% confidence interval using 5000 resamples, Hypotheses H1 to H6 were supported because their confidence interval did not include zero (Table 5). Thus, all hypotheses were confirmed. These results complete a basic analysis of PLS-SEM in our research. The result for PLS-SEM is shown in Figure 4.

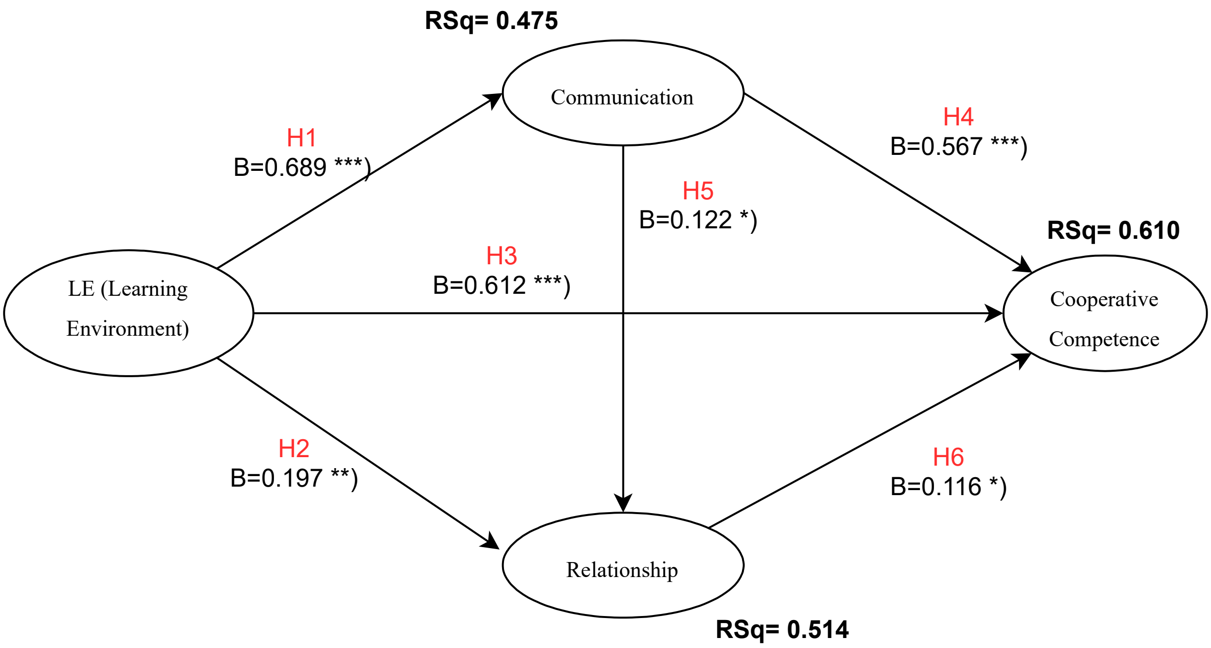

Figure 4. Results of testing the model significance * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Therefore, Figure 4 and Table 6 show the variance explained by R^2 in the dependent constructs and the path coefficients for the model and the effects on endogenous variables.

Table 6. Effects on endogenous variables (extended model).

Dependent Variable	R^2	Q^2	Antecedents	Path Coeff.	Correlation	Explained Variance (%)
Coop-comp.	0.610	0.396				61.0
			H4: Communic	0.122	0.625	7.62
			H6: Relations	0.116	0.562	6.51
			H3: LE	0.612	0.765	46.81
Communic.	0.475	0.251				47.5
			H1: LE	0.689	0.689	47.5
Relations	0.514	0.317				51.4
			H5: Communic	0.567	0.703	39.86
			H2: LE	0.197	0.588	11.58

5.4. Analysis of Efficiency and Satisfaction

Although the main objective of this study was to analyze the influence of the combination of OLE resources with active learning on the improvement of student relationships and cooperative competence, students' perceptions and opinions on the different learning resources and methodologies used were also gathered, as students' feedback is a key aspect in defining the quality and effectiveness of these tools and methodologies. Thus, in order to find out the efficiency of the OLE tools (virtual interactive exercises, teaching videos, gamification) and the learning activities (active learning, mobile-app activities, gamification), the students' opinion of these resources before the course was compared with their opinion at the end of the course. The results are shown in Table 7.

Table 7. Comparative efficiency of learning tools.

	Had Already Used (%)	Pre-Efficency	Post-Efficiency
Videos	77.01	4.498	4.574
Exercices/VLab	64.37	4.464	4.609
Mobile app.	62.45	4.138	3.737
Activ. Learning	55.17	4.188	4.266
Game in class	34.87	4.268	4.339
Game OLE	26.44	4.291	4.547

Regarding the results on students' degree of satisfaction with the OLE globally, Table 8 shows the questions and a summary of the students' answers. These values show that experience and appreciation of the OLE were certainly positive.

Table 8. Questions and results of the ole satisfaction survey.

OLE	Mean	STDev	STDErr
It was presented effectively	4.326	0.692	0.041
It was simple	4.269	0.734	0.043
I found it useful	4.574	0.561	0.033
The N° of exercises was appropriate	3.906	0.887	0.052
I found it motivating to use	3.996	0.897	0.053
I found it interesting	4.157	0.773	0.045
It enhanced my experience	4.369	0.692	0.041
It helped to pass the course	3.934	0.918	0.054
It helped me use my time better	3.819	0.950	0.056

6. Discussion

Structural equation modeling (SEM) was used to examine the impact of a web-based online learning environment, which includes interactive activities, virtual laboratories, teaching videos, and a game-based learning methodology, on student relationships and the development of cooperative competence.

According to the results, the proposed model to evaluate the hypotheses is completely satisfactory. Thus, simple and compose reliability were acceptable. Additionally, there were high levels of internal consistency reliability among latent variables. The independent explanatory variables, the values for validity and discriminant validity of the measurements were also acceptable.

All the hypotheses were tested and validated, and the relationships were positive, mostly with a high level of significance. Therefore, the results confirm the hypotheses.

As shown in Table 6, the LE created by combining the OLE resources and the learning approach (active, collaborative learning and gamification), clearly affects communication (H1), explaining 47.5%. Furthermore, the LE affects relationships (H2), explaining 11.58%. Likewise, as Gittel [61] states, communication plays a fundamental role in improving relationships (H5), accounting for 39.86% in our analysis. This indicates that communication fosters the relationships dimension, creating a climate that facilitates learning and cooperation.

As suggested by some authors, the acquisition and development of key skills such as cooperative competence can be improved through active learning strategies [17,18], collaborative learning [26,27], game-based learning [32] and also with online learning resources [5,38]. Therefore, in line with these authors, and as was hypothesized, the LE created by combining OLE resources and active learning strategies, collaborative learning and gamification, greatly affects the development and enhancement of cooperative competence (H3), explaining 47%.

The communication and relationship dimensions of the relational coordination model also affect the acquisition of cooperative competence, although with much fewer significant values than those of LE. Thus, the communication dimension explains (H4) 7.62% and the relationship dimension explains (H6) 6.51% of the acquisition and development of cooperative competence.

From the results, we can see that the OLE tools and the learning environment facilitated by them have a direct and significant influence on the acquisition and improvement of cooperative competence, and that they also have an indirect influence through communication and relationships, in line with the results of De Pablos et al. [64], Margalina et al. [65,66] and Gallego et al. [81].

On the other hand, with regard to the analysis of efficiency of the different learning tools and the level of satisfaction with OLE, Table 7 shows that the students' perception of effectiveness with each of the tools at the end of the course is slightly higher than their initial expectations, with the exception of the activities with mobile applications.

Moreover, it is noteworthy that there are no major changes between the pre and post values, due to students already having quite high expectations when they answered the questionnaire at the beginning of the course.

Additionally, in Table 7 it can be seen that the learning tool most previously known by the students was the use of videos, with 77% of students having already used them, and the least known was gamification both inside and outside the classroom, with 34.87% and 26.44%, respectively.

In any case, the rating assigned to each of the learning tools was quite positive. The satisfaction with OLE was also very positive, as can be seen in Table 8. These results show that the experience and appreciation of the learning process was very satisfactory and that the LE motivated and encouraged the students. Thus, in line with [32], increasing student engagement translates into enhancing learning and also cooperation skills.

7. Conclusions

Higher education institutions are required to do much more than just provide students with content knowledge, they must create quality educational processes in which students acquire skills and competences as well as knowledge, through appropriate learning resources and modes in order to converge with the needs of today's society.

This study contributes to the existing literature on the use of new educational technologies as it presents an online environment devised from scratch that integrates computer simulations, virtual laboratories, interactive activities and educational videos in a game-based approach.

The main objective of this study is to analyze the impact of this online learning environment combined with active learning methodologies on the improvement of relationships and the development of cooperative competence.

Our results indicate the following: first, the structural model developed in this research has proven to be a useful theoretical instrument to test and validate the proposed hypotheses. Therefore, this study constitutes a contribution to the literature supporting the effectiveness of structural equation modelling (SEM) to analyze the correlation of variables.

Second, the online learning environments combined with active and collaborative learning methodologies had a significant impact on students' relationship. Technology, with the right instructional approach, can make online learning more participative and collaborative. This learning environment supports and improves students' relationships both inside and outside the classroom.

Third, this learning environment leads to a strong and significant impact on cooperative competence acquisition. The participative and collaborative activities and the use of game based learning allow more interaction and dialogue between learners, which has contributed to creating a feeling of connectedness that promotes teamwork and the development of cooperative skills

Fourth, as expected, cooperative competence is also affected by the relational coordination model (communication and relationships). Improved relationships between students, but especially effective, frequent and timely communication and sharing of knowledge and goals, has a significant impact on the development of cooperative competence.

Students' feedback also revealed a high level of satisfaction with the OLE resources and a very positive attitude towards the active teaching method.

According to the results, virtual activities based on game-based learning and appropriate instructional strategies are key to engaging learners in the learning process and to promote commitment and involvement. Therefore, these kinds of activities should be appropriately designed to enhance learners' relationships and promote the development of cooperative competence.

Many of the changes experienced in higher education during the global pandemic sparked by COVID-19 will remain for a long time. It is foreseeable that the percentage of time spent on online learning will be higher than before COVID-19, and we must make sure that we do not fail in this educational transition. This study addresses important issues, such as improvement of relationships and the development of essential competences such as communicative and cooperative. Given the problem of the isolation of students in online and blended learning, these issues are especially relevant in the COVID-19 pandemic and also post-pandemic education. As the results show, technology and appropriate instructional strategies can play a key role in promoting the development of relationships and social competences. Therefore, the results of this study are valuable for researchers, academic institutions and educators to help them make the best decisions about which learning environments (learning tools and strategies) are most useful and efficient, to improve the learning process, but also to develop important skills for graduates' future careers.

This study addresses important issues in higher education, namely relationships and the development of essential competences such as communication and cooperation. As the results show, technology and appropriate instructional strategies can play a key role in promoting the development of these important skills for graduates' future careers. Hence, the findings of this study are valuable for academic institutions and educators to create efficient learning environments for competence development, by applying active and participatory learning strategies and designing the online learning tools that support them.

Some limitations should be noted. Firstly, with regard to the development of the OLE system, it has been created ad hoc from scratch, which implies certain limitations in terms of adaptability for other courses. The lack of appropriate virtual tools and the need to create web resources adds complexity, so further research is needed to achieve greater standardization. Secondly, with regard to the model used to carry out the research, despite the total variance explained for the dependent variables being quite high, it is possible that other predictors were excluded from the study.

In the future, we hope to add other modules to the OLE that will provide greater communication between students and facilitate the scalability and flexibility. We also intend to carry out longitudinal research using similar OLE in other subjects. The suggested study will evaluate how other factors such as gender or experience with the OLE may affect the model. This was not possible to assess in this present study due to the small sample size in both cases.

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