


Article

Sustainable Distance Education: Comparison of Digital Pedagogical Models

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Abstract: The literature shows strong evidence of how different learning models influence learning. The kind of model used is a basic variable that can either help or hinder sustainable education. The objective of this research is to analyse how digital pedagogical models of three kinds (collaborative, social, and independent) influence the learning experience. The study is based on a design that combines triangulation, a theoretical model, quantitative methods (descriptive analysis and contrast of means), and qualitative methods (discourse analysis, following the principles of grounded theory). The importance of social and collaborative models in sustainable education is proved; both types of models promote a positive learning experience. They strengthen inter-student relationships, a feeling of belonging to a community with shared interests, and feelings of membership and cohesion. An independent model may hamper students' perception of current knowledge and development of collaborative competences, in contrast to the more-interactive model. These results can be assessed in greater depth through future research exploring independent models' possible potential for analysing environmental problems and their tie-in to personal decisions.

Keywords: collaborative learning; digital pedagogy; social learning; independent or autonomous learning

1. Introduction

Education for sustainable development challenges reigning educational ideas, organisations, and even content, and at the same time, it deals with issues like cooperative skills and creative, reflexive, and critical thought [1]. It can thus improve education and teach students how to make sound decisions.

Sustainable digital education seeks to educate people about commitment and social transformation to facilitate the construction of a society that is increasingly responsible vis-à-vis future generations. As the United Nations [2] stated in 1987, this aspect is the key that defines the concept of sustainability. Sustainable ethical behaviour can never develop unless there is social commitment within the educational community and in the school itself. UNESCO tells us that when we place our focus on personalised learning processes, we make it harder to tackle social topics and topics related to sustainable development.

UNESCO [1,3] stresses the importance of social learning, and collaborative learning within a digital pedagogical model is the basic strategy that can help us attain sustainable education [4].

Let us begin by defining collaborative learning as learning that takes place in an organised group working cooperatively toward a specific shared objective [2] and interacting to reach academic objectives [5], where what the group can achieve depends on how all the group's members behave [6]. Collaborative learning seeks to transform how we learn and so facilitate the development of autonomy; improve information analysis, synthesis, and expression capabilities; and thus reach the group's shared goal [7–9]. This transformation requires a particular methodology implemented through certain

specific teaching activities; otherwise, we miss the entire point of collaborative work [10], and what is supposed to be collaborative may veer dangerously close to cooperative work, which obeys a different methodology [11]. Digital collaborative learning favours effective learning processes [12,13]. It is regarded as one of the most complete, effective learning models for digital and university contexts because it involves active [14], interactive [8,14–16], constructivist learning based on the processes of communication and interaction [17].

This research begins by framing the concept of social learning as a process of active participation in the practices of social communities that in turn influence the construction of one's own identity [18]. In a social learning model based on discussion and interaction on social networks, networks are regarded as environments that facilitate horizontal, non-hierarchical communication, knowledge acquisition, information and opinion sharing [19], and feelings of membership and cohesion [20]. They are spaces of social influence in the sense of "the effect whereby an individual's thoughts, feelings or actions are affected by other individuals" [21] (p. 274), and therefore participation in networks fulfils important social learning functions [22]. In addition, studies indicate that when students engage in discussion and reflection, their perception of the learning experience is improved [23]. Twitter has been defined as a conversation centre [24] and a space that strengthens the communication process and citizen influence [25].

The digital education proposals of the last few years have focused more on interaction- and communication-based models than on independent (or autonomous) learning models [26]. These collaborative and social learning proposals are not free of difficulties that may prevent smooth learning, such as the consideration that forcing students to take part in interactive processes compromises students' autonomy [27], lack of commitment among group members [28], students' observed resistance against interacting publicly and/or on social networks [29], supervening limitations due to learning style [28], or students' preference for autonomous solo work under their own, unshared responsibility [30]. In fact, the importance of individual tasks as opposed to online activities and discussions has been defended [31]. The basis is the definition of the independent learning model as the model that offers students various degrees of freedom and takes place through sundry means of communication, but forces students to assume responsibility autonomously for their own learning process both instrumentally (beginning the activity and performing it without seeking help) and emotionally (not seeking regard or approval for the work they are doing) [32].

The present study adds evidence to the literature on how learning model type influences different variables of the teaching and learning process in sustainable higher education. The objective is to analyse the influence of the digital pedagogical model (either collaborative [C], social [S], or independent [I]) on the learning experience, examined in terms of four concepts: general assessment of the pedagogical proposal, knowledge acquisition (social, active, current, theoretical, and practical knowledge), learning processes (constructivist, connectivist, social, active, critical, and reflexive learning), and lastly the development of feelings of group membership and cohesion.

The research question is this: How does the digital pedagogical model influence the learning experience?

To operationalise the general objective, the following Hypothesis 1–4 were proposed (Figure 1):

Hypothesis (H₁). *The general assessment of the learning experience is differentially influenced by the learning model used.*

Hypothesis (H₂). *The learning model used exerts a differential influence on the knowledge acquisition experience: The social learning model facilitates the perception of the acquisition of current, active knowledge, in contrast to the collaborative learning model, which favours the perception of the acquisition of collaborative work competences, and the independent model, which lends itself more to technical and practical knowledge.*

Hypothesis (H₃). *The constructivist, connectivist, active, social, participatory learning experience is favoured by the social model and the collaborative model, in contrast to critical, more-reflexive learning, which is facilitated by the independent model.*

Hypothesis (H₄). *Feelings of membership and cohesion are favoured by the collaborative and social learning models, but not by the independent model.*

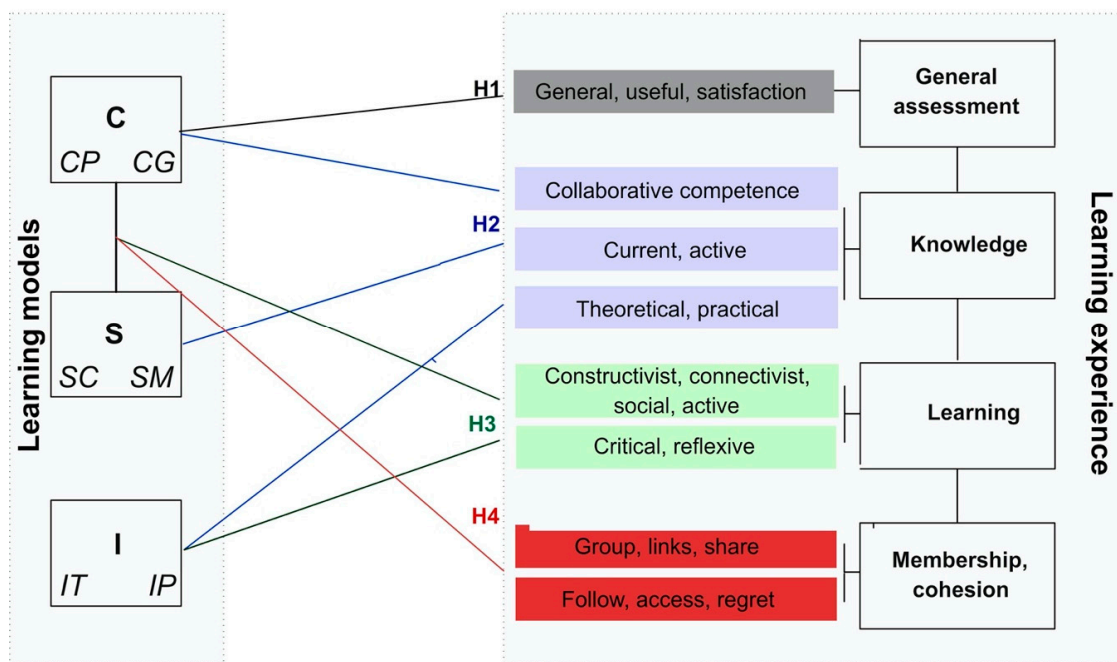


Figure 1. Proposed model.

2. Materials and Methods

2.1. Context of the Study

Spain's National Distance Education University (Universidad Nacional de Educación a Distancia or UNED), the context in which the research reported in this article took place, is based on an increasingly digital educational system that seeks to facilitate equal access to quality university education, in line with sustainable development goal 4 of the 2030 Sustainable Development Agenda and more specifically targeting goal 4.3., "Ensure equal access for all women and men to affordable and quality technical, vocational, and tertiary education, including university," and goal 4.4., "Substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs, and entrepreneurship."

This study was conducted among students enrolled in four subjects from the undergraduate and master's degree curricula in the 2019–2020 academic year. As part of the Methodologies Based on Connected, Active Collaborative Learning Project, these classes employed various learning models to train future education professionals.

The three digital pedagogical models evaluated in this study are the collaborative learning model, the social model, and the independent (or autonomous) learning model. These models share the objective of developing attitudes, values, and competences that enable students to respond to future social and educational challenges in the framework of sustainable education.

2.1.1. Collaborative Learning Model (C)

The collaborative pedagogical design adhered to the parameters indicated by Mora, Merodio, and Martínez [33]. The learning model and the objectives were defined; pre-recorded video classes guiding students through the activity and the subject requirements, the course syllabus, and the schedule of activities and interactions were presented; the best tools for the learning process were established [34,35]; and lastly the instructors' involvement was ensured, as Pérez Torres [36] suggests, to motivate students more strongly.

The proposed activities called for students to detect and analyse a social problem that had developed on a social network. Each student had to select a single case study (a social network problem related to a group of students from a school and/or social centre) and complete the process of detecting, analysing, and proposing possible solutions to the problem.

Two variants of the collaborative model were analysed:

1. Collaboration as a class group (CG): The task had to be done in cooperation with the entire group/class. The group/class was not divided into subgroups. The group was expected to work together on each of the activities proposed by the group members. The model was applied to a subject in the undergraduate curriculum for one semester. Twitter and the class discussion forums were used as communication tools. Using these tools, each student selected a social problem in progress on a social network (e.g., harassment, insults, gender discrimination) and presented it to the entire group/class, which discussed whether the problem would be a good case study and what solutions might be applied to it.
2. Collaboration in small groups (CP): The teaching team created working subgroups of six to eight students (randomly assigned to the subgroups). Private work areas for each subgroup were created within the virtual course. The model was applied to a subject in the postgraduate curriculum for half a semester (three months). Twitter and the class discussion forums were used as communication tools. To complete the activity, each student selected one case study (a social network problem having to do with the group of students at a school and/or social centre) and performed a process whereby they detected the problem, analysed it, and proposed a possible solution. The students used the selected social network and the virtual course's forums as their means of communication.

Both models were thus designed on the basis of the same kind of task, but they differed in how the work was to be done and how the task was to be accomplished.

2.1.2. Social Model Based on Academic Discussion on Social Networks (Twitter) (S)

"Social network" is now used practically as a synonym for the concept of the digital social network. From this perspective, social networks are not merely key spaces; because social networks are made up of people and their relationships with each other, we define them also as a set of relationships that can influence people's lives by creating a specific social environment [37]. As Christakis and Fowler [38] assert, to comprehend how society works, it is vital to understand how interpersonal connections give rise to new experiences beyond the individual realm. Although social networks have been studied from different perspectives, an integrating focus means adopting a social perspective.

At the core of the social model lay immersion in the Twitter social network, not only from a practical/technological standpoint, but also, and much more importantly, as a space for creating a community of shared interests that students can go to even after the course is over.

From this perspective, two variants were designed:

1. Short-term discussion (SC): Two discussions to be held in two weeks. One discussion per week. During the first week, students had to discuss, interact, and exchange opinions and resources about the purpose social networks serve, how that purpose becomes twisted, abuse, opinion control/manipulation, and privacy. During the second week, students discussed education,

digital culture, and collaboration; how these fields are connected; what networks contribute; and what the negative aspects and positive aspects are. The model was applied to a subject in the postgraduate curriculum for half a semester (three months). Twitter and the class discussion forums were used as communication tools.

2. Medium-term discussion (SM): A discussion to be held over 20 days. Students had to discuss and interact over the question of how they would evaluate competences in secondary education and then make proposals related to the topic. The model was applied to a subject in the postgraduate curriculum for two months. Twitter and the class discussion forums were used as communication tools. The discussion topic was directly related to the course's subject matter, so the aim was for students not only to acquire certain theoretical knowledge, but also to experience and address the difficulties entailed in participating in an open-network educational community and to learn first-hand the possibilities and difficulties of using specific social networks in education within a reflective, critical context.

Both models used Twitter for academic discussion, although they differed in the number of discussions held and the time allowed for discussion. In the SC model, two discussions took place in the short term, which means the process was more intense. In the SM model, there was only one discussion in a 20-day period.

2.1.3. Independent (or Autonomous) Learning Model (I)

This model's design was based on the work phases noted by Pintrich [39] and Zimmerman [40]. Each student set her or his own learning objectives with the support of a process for self-regulating one's thoughts, emotions, conduct, and motivation [39]. This took place in three phases: planning and preparation, execution, and evaluation [40].

This model featured two variants:

1. Theoretical work (IT): Students had to perform a set of theory-related/hands-on activities whose objective was to facilitate learning the subject and to help acquire the target competences as established in the learning results. Students selected six activities from a range of choices, including "create a dossier of definitions," "prepare a personal outline, summary, and analysis," "prepare a unit of study," "prepare a comparative grid," "make a mind map of the contents of a study unit of your choice," "prepare a document with all the information you can get from the media (press, radio, TV, internet, etc.) about a course topic you are interested in," and "propose an open activity by your own initiative related to practical cases in school organisation and management." The model was applied to a subject in the undergraduate curriculum for a semester. Discussion forums and web conferencing were used as communication tools.
2. Technical and practical work (IP): Using a specific programming language, students had to programme an interactive story, game, and/or animation using a particular kind of software. The objective was to find a simple, innovative way to develop basic skills in programming for children. The model was applied to a subject in the undergraduate curriculum for a semester. Students used free programming software. They submitted any questions to the discussion forums. Students received support via web conference at the start of the semester; this was the designated means of communication for the activity.

2.2. Population and Sample

The study sample was 176 future education professionals (social educators, specialists in education theory, secondary school teachers) enrolled in classes on four subjects (two undergraduate subjects and two postgraduate subjects) in which various digital pedagogical models (collaborative, social/participatory, and independent/autonomous) were used (Table 1).

Table 1. Sample.

Subject	Model						Total
	Social		Collaborative		Independent		
	SM ¹	SP ²	CP ³	CG ⁴	IP ⁵	IT ⁶	
Postgraduate	43	36	18	0	0	0	97
Undergraduate	0	0		20	17	42	79
Subtype total	79		38		59		176

¹ Short-term discussion (SC); ² Medium-term discussion (SM); ³ Collaboration in small groups (CP); ⁴ Collaboration as a class group (CG); ⁵ Technical and practical work (IP); ⁶ Theoretical work (IT).

2.3. Design and Data Collection Instruments

The study was based on a design that combined triangulation, a theoretical model, quantitative methods (descriptive analysis and contrast of means), and qualitative methods (discourse analysis, following the principles of grounded theory) [41]. The study employed the SPSS ver. 24 package (statistical analysis) and Atlas Ti HM software (content analysis).

The quantitative study was conducted on the basis of a descriptive analysis and contrast of means (factorial ANOVA, multivariate linear model) to ascertain how the learning model used (collaborative, social, or independent) influenced the learning experience as measured via these dependent variables: general assessment of the proposal, knowledge acquisition, learning processes, and development of feelings of group membership and cohesion. The distribution of the variables was not normal; for this reason, and to confirm the ANOVA data, the non-parametric Kruskal–Wallis H test was used. After the difference between means was found, the Bonferroni post-hoc test was applied to locate the pairs in which the differences lay. In addition, the tests' effect size was found (eta squared).

Data were collected using an ad-hoc Likert survey (<https://cutt.ly/kyMxOCy>) with six open and 20 closed questions concerning the following variables: general matters of quality, subject usefulness, analysis of the learning process and knowledge acquisition, collaborative work, and membership and cohesion.

The survey was organised in six dimensions: general evaluation of the subject (four items on quality, usefulness and satisfaction), analysis of the communication and interaction process (seven items), learning and knowledge acquisition process (seven items), collaborative work (four items), pedagogical innovation (three items), and membership and cohesion (four items). The information required for the research objective was selected from the variables stated above.

The initial version of the survey was modified in response to contributions from three faculty experts in the knowledge area. As a check of reliability, Cronbach's alpha was found to be 0.964, which is much higher than the recommended 0.70. Content validity was based on the literature, in the variables considered fundamental by authors such as Kurucay and Inan [42] (demographic data, satisfaction, interaction, perception of collaboration, perception of learning) and Luo et al. [43] (student–student interaction, student–instructor interaction, interaction with content, membership and influence).

The factors and their values are presented in Table 2.

The qualitative study [44,45] was based on discourse analysis [45,46] of the answers to the survey's open questions about the value of the communication and interaction process and the development of a feeling of membership and cohesion. These questions sought to expand on the information from the quantitative data. They were analysed as indicated by García-Llamas et al. [45]: 1) definition of the content universe and sample selection; 2) choice of the unit of analysis; and 3) establishment of categories.

The open questions focused on exploring aspects related to interaction, membership, and cohesion. Some questions asked students about their interest in interacting with classmates (interaction). Other questions inquired whether students felt like a member of the classmate group, whether they saw

themselves as part of the group/class, whether or not they had bonded with classmates, and whether they felt they shared similar needs and objectives with other students (membership). Lastly, the survey examined students' intention to keep participating in the virtual course and/or social network and the underlying reasons, students' interest in accessing the virtual course and/or social network frequently in future, and lastly whether students felt that losing access to the course/social network might be a disadvantage and how serious that disadvantage would be.

Table 2. Factors and values.

Factors (Models)	Values (Model Subtypes)
Collaborative learning model (C)	Class group collaboration (CG) Collaboration in small groups (CP)
Social model based on academic discussion on social networks (Twitter) (S)	Short-term discussion (SC) Medium-term discussion (SM)
Independent (or autonomous) learning model (I)	Theoretical work (IT) Technical and practical work (IP)

Models and subtypes of models.

3. Results

The research results show the influence each digital model has on the learning experience, knowledge acquisition, and the creation of feelings of membership and cohesion.

3.1. H1. The General Assessment of the Learning Experience Is Differentially Influenced by the Learning Model Used

Over 50% of the students ranked the general learning experience highly or very highly in all dimensions (general assessment, usefulness, and satisfaction). No significant differences were observed between learning models (Table 3).

Table 3. Kruskal–Wallis H test for general assessment of the learning experience.

	Test Statistic		
	General Assessment	Usefulness	Satisfaction
Kruskal–Wallis H	15.016	5.968	9.067
dof (Degrees of freedom)	5	5	5
Asymptotic sig.	0.010	0.309	0.106

Variable: General assessment of the learning experience.

3.2. H2. The Learning Model Used Exerts a Differential Influence on the Knowledge Acquisition Experience: The Social Learning Model Facilitates the Perception of Acquisition of Current, Active Knowledge, in Contrast to the Collaborative Learning Model, which Favours the Perception of Acquisition of Collaborative Work Competences, and the Independent Model, which Lends Itself more to Technical and Practical Knowledge

A total of 67% of the students felt they had acquired knowledge at a high or very high level. When asked about the type of knowledge they had acquired, more than 52% reported that they had acquired, at a high or very high level, all types of knowledge (knowledge of the subject, technical knowledge, current knowledge, theoretical knowledge, and collaborative competences) (Figure 2).

Significant differences in knowledge acquisition are observed concerning knowledge of the subject ($F(2.93)$, sig. (bilateral) = 0.014), current knowledge ($F(4.77)$, sig. (bilateral) = 0.000), theoretical knowledge ($F(4.77)$, sig. (bilateral) = 0.000), and collaborative working competences ($F(5.32)$, sig. (bilateral) = 0.000). The Kruskal–Wallis U test confirms the differences (asymptotic sig. 0.001, 0.023, and 0.001, respectively). For all variables, the effect size is small (R^2 between 0.014 and 0.110).

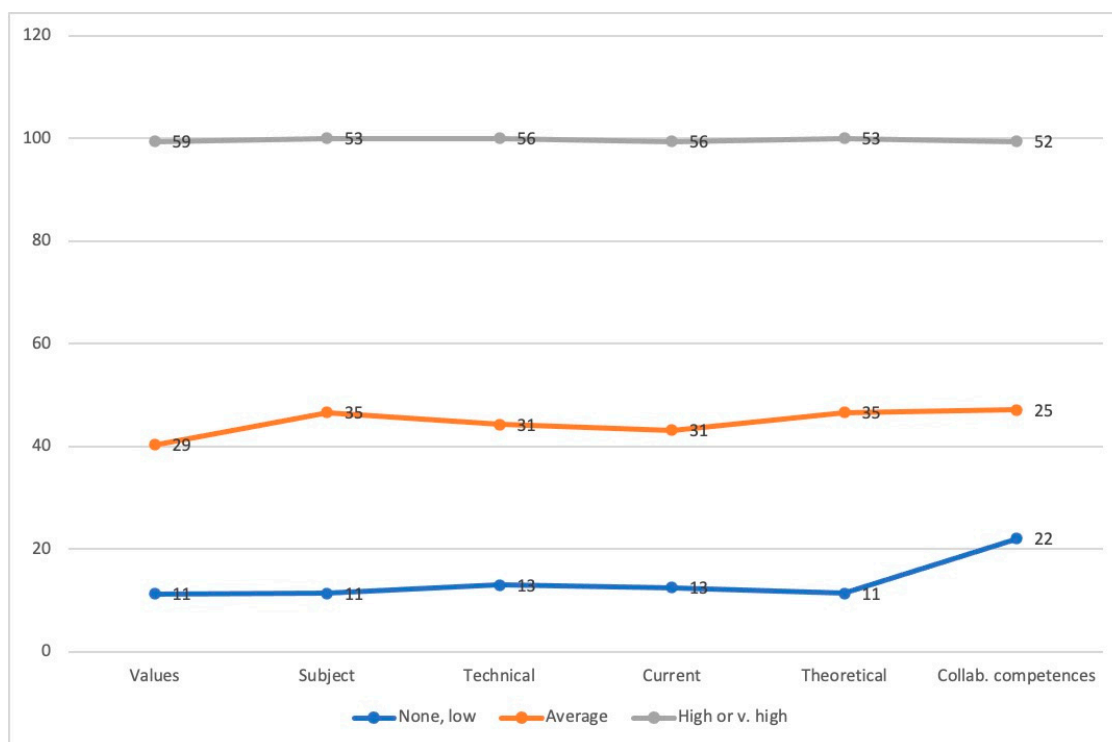


Figure 2. Perception of acquired knowledge (percentages).

The students who participated in the independent theoretical model reported a lower acquisition of current knowledge (news, projects, events, etc.) than did those who formed part of the medium-term discussion social model (sig. = 0.003), the class group collaboration model (sig. = 0.002), or the small group collaboration model (sig. = 0.015). In addition, the students in the independent theoretical model had a lower mean perception of having developed collaborative competences than did the students in the two collaborative models (sig. = 0.003 and sig. = 0.004).

The students in the class group collaborative model reported the best perception of acquired knowledge (mean of 4) of all three types (subject, theoretical, current), maintaining significant differences (Bonferroni, sig. = 0.014) with the medium-term discussion social model in subject knowledge acquisition and theoretical knowledge acquisition.

3.3. H3. *The Constructivist, Connected, Active, Social, Participatory Learning Experience Is Favoured by the Social Model and the Collaborative Model, in Contrast to Critical, more-Reflexive Learning, which Is Facilitated by the Independent Model*

More than 63% of the students reported having developed the different types of learning (critical and reflexive, constructivist, connectivist, social, and active), except in independent learning (39.2%).

Significant differences were observed in social learning (F (7.88), sig. (bilateral) = 0.000) and independent learning (F (5.83), sig. (bilateral) = 0.000). The Kruskal–Wallis U test confirmed the differences (asymptotic sig. 0.000). For all the variables, the effect size was medium (R² between 0.164 and 0.121).

The students in the independent theoretical model had less perception of having acquired social learning than did the students who participated in the social models (Bonferroni = 0.003 in SM model and 0.000 in SC) and collaborative models (Bonferroni = 0.0032 in CP model and 0.049 in CG). Furthermore, students in the independent model had a greater perception of having engaged in independent learning than did students in the medium-term discussion social model (Bonferroni, sig. = 0.000), the short-term social model (sig. = 0.020), or the small group collaborative model (sig. = 0.022).

3.4. H4. Feelings of Membership and Cohesion Are Favoured by the Collaborative and Social Learning Models, but not by the Independent Model

Most of the students developed a feeling of membership at a high or very high level in all the learning groups: 60% reported feeling like part of the group/class, 45.5% reported having developed ties to classmates, and 46% said they felt that they and their classmates shared similar needs and objectives.

To examine the feeling of cohesion, it was found that at a high or very high level, 45.5% reported that they intended to prolong their participation in the virtual course and/or social network, 47.2% reported that they would like to have access to the virtual course and/or social network frequently in future, and 42% said that they would consider it a loss if they could no longer use the virtual course and/or social network in future.

Significant differences were found in all aspects (membership and cohesion) except for the cohesion variable in the feeling of loss at not having access to the virtual course and/or social network in future. The data were confirmed with the Kruskal–Wallis test (Table 4).

Table 4. Kruskal–Wallis test for “feelings of membership and cohesion”.

	Test Statistic					
	Membership			Cohesion		
	Group/Class	Tie	Shared Interests	Continue Course	Access	Regret
Kruskal–Wallis H	35.290	35.769	25.548	23.986	22.300	12.878
dof	5	5	5	5	5	5
Asymptotic sig.	0.000	0.000	0.000	0.000	0.000	0.025

“Feelings of membership and cohesion” variable.

Students working in the independent theoretical model displayed significantly lower means in membership feeling in all three values analysed (feeling like part of the group/class, feeling of creating ties to other students, feeling that they and classmates shared similar needs and objectives), in contrast to the social models (SM and SC) and the small group collaborative model (Table 5). In addition, the students in the independent practical model expressed a lesser feeling of having created ties to classmates than did the students in the small group collaborative model (Bonferroni, sig. 0.023).

Table 5. Bonferroni post-hoc test for “membership feeling”.

Model		Membership Feeling		
		Feeling Like Part of the Group/Class	Feeling that Ties Are Created	Feeling that Needs and Objectives Are Shared
IT	SM	0.000	0.000	0.006
	SC	0.000	0.000	0.002
	CP	0.000	0.000	0.005

“Membership feeling” variable.

As a measure of the feeling of cohesion, the intention of prolonging participation in the virtual course and/or the social network among students in the small group collaborative model was observed to have a significantly higher mean than among students in the medium-term discussion social model or the independent theoretical model. Furthermore, analysis of the sentimental value of loss if students could not access the virtual course and/or social network in future revealed a lower mean in the independent theoretical model than in the short-term discussion social model (0.025) or the small group collaborative model (0.003).

Qualitative analysis confirmed that the students who participated in the independent model made it clear that they had learned without the need to interact with others and without relying on others' help (“Interaction was not necessary, which is sad, and was not encouraged outside the forum” (S167)). These students had difficulty developing a feeling of membership and cohesion, in contrast to

the students in the social and collaborative models (“I worked and studied alone” (S173); “I do not have any relationships” (S130)).

In contrast, qualitative analysis also showed that the students who participated in the social and collaborative models valued the fact that they and their classmates had shared objectives: “Because we’ve gotten along, and we have the same concerns and problems having to do with the degree” (S116); “Everybody in our group is pursuing the same objectives, and the best thing about attending UNED is the way students work together” (S152); “Because relations in the group are quite satisfactory. We share some interests and objectives. Everybody’s taken into consideration and account, with respect and in a spirit of building together” (S137). These students stressed the importance of mutual support: “It’s comforting to see that, if you ever feel lost, there’s always somebody else who feels the same, so you’re not alone” (S90); “I’ve found a great group of classmates, and we help each other all the time” (S36). They identify with the group: “We’re all in the same boat. Being in a distance education programme is lonely, but when you have classmates’ support, in Facebook groups, in forums, you identify with them” (S62). Lastly, the students perceived working as a group as providing added value: “The class/group work is very balanced, I feel, and group members are showing a lot of interest in what we’re doing” (S76).

4. Discussion and Conclusions

The first conclusion is that the general learning experience (general assessment, usefulness, and satisfaction) was valued positively by the students in all models, without significant differences between models. Hypothesis 1 is not confirmed. The model type does not significantly influence the general assessment of the learning experience. Although the models that reinforce social and cooperative skills were expected to result in higher satisfaction and a higher score, it was observed to be otherwise. No significant differences were found in these variables.

Interestingly, 60% of the students felt that they had acquired knowledge (subject knowledge, technical knowledge, current knowledge, theoretical knowledge, and collaborative competences) and developed their learning capacity (for critical and reflexive learning, constructivist learning, connectivist learning, social learning, and active learning) at a high or very high level.

The learning model’s influence on students’ perception of knowledge acquisition was small. Therefore, hypothesis 2 is confirmed only on some points. The independent model was not observed to lend itself more to the acquisition of technical and theoretical knowledge; in fact, acquisition of theoretical knowledge was facilitated within the medium-term discussion social model and the class group collaborative model. An independent model may hamper students’ perception of current knowledge and development of collaborative competences, in contrast to the more-interactive collaborative and social models.

Using social models and small group collaboration models makes it easier for students to share information and knowledge than using models based on theoretical or practical activities performed independently. No significant differences were observed between the two types of independent models; therefore, it is concluded that the most influential characteristic is the independent nature of the learning process, instead of the type of activity (i.e., theoretical or practical) that the student performs. Also, it was found that students tend to ask for information when working collaboratively in small groups, as opposed to when using independent models.

Hypothesis 3 is partially confirmed. On the one hand, the social and collaborative models favour social learning; on the other hand, all the models have the same weight in the constructivist, connectivist, active, critical, and reflexive learning experience. The perception of social learning (learning in society thanks to contributions from other participants such as students and instructors participating, sharing, and engaging with each other) reinforced by the independent theoretical model is significantly worse than the perception of social learning reinforced by the social and collaborative models. The independent model strengthens the perception of independent learning, learning alone thanks to independent effort, where students autonomously bear responsibility for their own learning

process [32]. Students express this clearly when they say they are learning alone and do not look for help or deal with others, thus confirming both types of independence (instrumental and emotional) reported by Moore [33].

The last conclusion is that all these results show that collaborative learning is a very complete model for use in digital and university contexts; it is active [14] and interactive [7,8,15,16], and it relies especially on processes of communication and interaction [17]. The collaborative model shares these characteristics with the social model, which is based on discussion on social networks.

As we have seen, the type of activity proposed in the independent model did not generally influence students. These data are striking, because the technological activity based on programming an interactive story, game, and/or animation was expected not only to engender reports of greater satisfaction and usefulness, but also to make significant differences in students' perception of knowledge acquisition and practical learning.

The qualitative and quantitative data reveal the value students place on interacting, sharing resources, and learning with classmates. This aspect is common to the social model and the collaborative model. Both models are potentially valuable for learning about interaction and membership, creating social communities based on a more-informal communication process of sharing ideas [19]. The data confirm the results, indicating that these interactions boost a feeling of group belonging [26,30,31], membership, and cohesion [26]. In short, hypothesis 4 is confirmed: Feelings of membership and cohesion are favoured by the collaborative and social learning models, but not by the independent model.

This study demonstrates the importance of social and collaborative models in the framework of sustainable education. Both promote a positive learning experience and reinforce feelings of membership and cohesion. All these aspects are essential if the educational community is to reach its goal of getting students to engage socially, as the UN [2] report states. Students in the independent model displayed individualistic feelings far removed from a sustainable focus; they did not generate feelings of being connected with others, they did not feel like part of the group/class or feel that they shared needs and objectives, nor did they display any intention of prolonging their participation in the virtual course and/or social network or accessing the virtual course and/or social network in future.

The independent model, by definition, involved an autonomous learning process, which proved itself generally effective. Even so, to enhance students' perception of being part of a group and part of society, the course could include specific units related to sustainability.

It is confirmed that an individualised learning process could make it difficult for academic institutions to deal with social issues and issues in sustainable development [1,3], in contrast to models that favour interpersonal relationships, be it through intense academic discussions on Twitter and/or by working in collaboration. In social and collaborative models, students especially value teamwork, mutual support, and the fact that they share objectives with their classmates. Students stress the importance of mutual classmate support in distance education, where it is often hard to really see other people, to feel that there actually is another person out there with whom one can work, who can provide support and also needs support. The qualitative analysis confirms that the students who participated in the independent model had difficulties simply realising that other people existed.

These results can be assessed in greater depth through future research by exploring independent models' possible potential for analysing environmental problems and their tie-in to personal decisions. Research could look into how the independent model influences topics where individual responsibility, decision making, and our short-, medium-, and long-term contribution to society as a whole and our planet's sustainability play a leading role. It would be interesting to put to the test an independent learning model that seeks to understand how our life depends on others and in turn others depend on our decisions. This idea could seed future research into independent learning models.

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