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# What is the maturity level of circular economy and bioenergy research addressed from education and communication? A systematic literature review and epistemological perspectives

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ABSTRACT

The role of education and communication is crucial to achieving the transition toward a circular economy (CE). Achieving cognitive, attitude and behavioural changes in the consumer and general population is a very complex process which requires mature scientific knowledge created by specialists. The current study aims to evaluate the degree of maturity of research on CE and bioenergy carried out from the areas of education and communication which are published in scientific literature between 2009 and 2019. The object of study have been scarcely approached from epistemological and methodological point of view, which is the novelty value of this study. To achieve the goal a systematic literature review (SLR) has been carried out on 74 peer reviewed scientific articles and conference papers. The records have been subjected to a clustering process (qualitative analysis) and a subsequent univariable (frequencies and vertical percentages) and multivariable quantitative analysis (comparison of column proportions). The studies' theoretical approaches were identified and the levels of formalisation, the predominant objectives and the hypothesis were analysed. In addition, the analysis of the research areas of studies reveals the epistemological process and outcomes of the literature. Several conclusions are drawn such as the scientific literature in this field is limited in scope. Moreover, from an epistemological perspective, descriptive studies are predominant, mainly addressed from the field of engineering, as well as analytical studies, which are mainly undertaken from Social and Legal Sciences. There are two main groups of articles based on their purpose: those which seek to describe, detail or define; and those which are more innovative, which analyse, establish or deconstruct the phenomenon. The results also show that the level of methodological and theoretical formalisation is limited, which indicates that research is in an initial stage. The foregoing results lead authors to conclude that the object of study has a low level of maturity.

## 1. Introduction

The current economy and consumption of resources cannot be dissociated (Ward et al., 2016), as the richer a country is, the more resources it consumes (Rammelt and Crisp, 2014). This is why it is so important to transform the current linear economic model into one which incorporates sustainable spiral loop systems, such as the circular economy (CE) (Stahel, 1982) or Cradle to Cradle framework (McDonough and Braungart, 2002). These seem to be the best solution to undertaking the implementation of the 2030 sustainable development goals (United Nations Division for Sustainable Development, 2015) with the objective of reducing the carbon footprint of the planet. The ambitious European Green Deal proposes, for 2050, transforming the industrial sector, strengthening legislation, renovating buildings and transforming mobility, as well as investing in education and training systems, life-long learning and social innovation (European Union. European Commission, 2020). This transformation also implies taking into account the role of bioenergy which is crucial to reduce the carbon footprint in addition to contributing towards ecosystem improvement while considering biomass waste as a primary source for energy generation (Reid et al., 2020) and industrial high value products (Souza et al., 2017a). The amendment incorporated by the European Commission in

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Directive (2008)/98/EC on waste (European Union, 2017), which obligates European States to ensure the selective separation of biowaste, boosted this transition in Europe. However, such a drastic change is affecting –and will affect– businesses, as well as consumers and users (Ellen MacArthur Foundation, 2013) who will inevitably also have to undergo a process of transformation of beliefs (knowledge), and above all, habits. Therefore, the role of education and communication is crucial in the process of transforming society toward the new circular economy because they are strategic elements of allowing this transition.

Consequently, the contribution of academia in the field of CE and bioenergy addressed from education and communication areas is considered indispensable and the state of scientific literature in this field is still very unknown. Aiming to supply a clearer picture of the status of current state of art in this specific field, this innovative research has been developed. For its elaboration, authors declare a primary hypothesis (PH) that establishes that the scientific literature which is made up of the areas of communication or education related with the CE and bioenergy show that research has a low level of maturity. The PH lead authors to declare the primary objective (PO) of the research that reads: PO is to evaluate the level of maturity of research on CE and bioenergy carried out from the areas of education and communication and which are published in scientific literature.

Since maturity of literature is a broad term, authors declare specific hypotheses (SH) that lead to define specific objectives (SO) and help to demarcate the aspects to be analysed in order to stablish the level of maturity of the literature:

- (SH1.) Social Sciences are the predominant discipline from which the object of study is addressed. → (SO1) Analyse the main areas of study.
- (SH2.1) The predominant epistemological approach is descriptive because studies superficially address the object of study, and (SH2.2) "educative/teaching innovation" studies are predominant (see section 2). → (SO2) Establish the epistemological approach carried out.
- (SH3) The level formalisation carried out at a theoretical level is low. → (SO3.) Identify the theoretical approaches carried out and their level of formalisation.
- (SH4.) The majority of studies explicitly declare objectives and have the objective of describing and detailing. → (SO4.) Detail the predominant objectives of the studies.
- (SH5.) The majority of studies do not explicitly declare the hypotheses. → (SO5.) Describe the level of hypothesis declaration.

### 1.1. The role of education in the transition toward the CE

CE has been widely studied from many disciplines and become more and more known concept among academics and outside the scientific sphere. The concept incorporates many meanings depending on the approach, although it has always had roots in the sustainable development concept (Tomislav, 2018). A considerably extended and accurate definition of CE is the one formulated by Kirchherr et al. (2017). It exposes that it is an economic system whose goal is substituting the "end-of-life" concept with "reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes" in all economic levels, and implies "creating environmental quality, economic prosperity and social equity".

In line with CE, the production of bioenergy supports the aim of reusing and recycling. Bioenergy is renewable energy that uses biological material to be produced rather than fossil carbon sources (Williams, C. L. et al., 2015). It is a sustainable alternative that supports sustainable development and considerably reduces $CO_2$ emissions (Chum et al., 2011). However, the implementation of an ethical use of bioenergy to achieve sustainable development production requires as well as implementation of technology and development of local knowledge (Souza et al., 2017b). The latter is crucial to develop critical thinking and promote the formation of well-informed citizens (McCormick, 2010) and education can help in boosting the spread of knowledge either about CE or bioenergy.

The interest of the academic community in the incorporation of strategies which increase critical thinking with regard to CE, bioenergy and environmentally responsible action in school is undeniable. The scientific evidence seems to confirm that there is a direct relationship between level of education and development of behaviour committed to the environment (Starr and Nicolson, 2015) whether through responsible purchasing habits or recycling (López-Mosquera et al., 2015). The larger the population that has only primary and/or lower secondary education, the lower the rate of recycling (Pelău and Chinie, 2018), which means that people with basic studies have lower probability of recycling (Arbués and Villanúa, 2016).

For Özbaş (2016), it is evident that learning, the social environment and the critical environment are factors which directly affect the intention of students to consider bioenergy as a more sustainable alternative. Promoting this atmosphere in school begins with training teachers on "sustainability, bioenergy, and bio-products from natural resources and wastes" (Mitra et al., 2015). Including knowledge on environmental education in textbooks is not sufficient if teachers and trainers are not motivated (Halder et al., 2014). This prior training and involvement of teaching staff is necessary to achieve a change of perception among students.

For the scientific community it is important to direct attention toward the creation of models for communicating knowledge of this nature at early ages (Halder et al., 2016). Likewise, there is a need to also incorporate thoughts on the CE at higher education institutions, not only so that the institutions and infrastructures themselves act responsibly (Mendoza et al., 2019a), but also to improve the presence of related specific educational programmes; for example, those related with bioenergy (Watkinson et al., 2012), which would ensure that the talent of students favours the development of a sustainable future.

However, specific training is not sufficient. Knowledge must be incorporated transversally in educational programmes. Thus, Andrews (2015) concludes that the acquisition of knowledge on sustainable product design by engineering students may have an effect on their personal and professional behaviour, and Kopnina (2019) concludes that bachelors' students who understand and analyse case studies of real businesses may increase both their understanding of circular economy production processes as well as their critical skills (Williams, M. et al., 2017). With this intention, the CE100 programme (Ellen MacArthur Foundation, n.d.) undertakes awareness raising and training work with the participation of businesses and higher education institutions, necessary in this process. The scientific literature shows that a significant part of these actions are being carried out with bachelors' and masters' degree engineering students as seen in several studies –such as the ones of Maruyama et al. (2019), a descriptive case study from Brazil and Colombia, Ormazabal et al. (2017), a Spanish case study, Ramírez and Ramírez (2015), which was carried out at the Tecnológico de Monterrey, or the one of Williams, I. D. et al. (2018), a case study executed in a United Kingdom wastewater treatment facility– through research activities which require them to become actively involved (Castillo et al., 2016). Furthermore, the use of active methodologies improves the motivation of students, as well as promoting their critical thinking (Whalen et al., 2018). The incorporation of new methodologies in various areas – such as the industrial sector of manufacturing (Lanz et al., 2019), the entrepreneurship sector (Kenny et al., 2013), the energy design education sector (Esparragoza and Mesa-Cogollo, 2019) and the fashion design sector (Hall and Velez-Colby, 2018)– seem to be an element of consensus, as reflected in the scientific literature.

### 1.2. Communication of the circular economy to go beyond the education sector

Communication plays a fundamental role in the transition toward

the CE. It goes beyond the academic field, as the business world and the general public must have access to knowledge related with CE (Ellen MacArthur Foundation, 2013). Businesses must understand that their survival depends on the implementation of the principles of CE, which involves the incorporation of new roles associated with communication, such as user experience designers, data storytellers, customer experience officers and qualified analysts (Vassileva and Ivanov, 2017), which will allow the identification of needs of consumers and users, listening to their demands and establishing conversations with their consumers.

However, achieving cognitive, attitude or behavioural changes in the consumer is a very complex process. Persuasive communication is a tool which may help the conscious change of behavioural attitudes, perceptions of the product and behavioural intentions of consumers (Muranko et al., 2019). Likewise, the communication channel must be appropriately selected. For students who participated in the study by Halder (2014a), the media is the most valued source of information for obtaining information on bioenergy. This reveals the important role that it plays in this process toward CE. In this sense, the press is key, as it plays an important role for raising awareness of bioenergy and other aspects related with the CE (Skjølsvold, 2012).

Today, in addition to the traditional media, there are social networks, which can be used to improve information processes (Uren et al., 2016) and obtain valuable data on behaviour patterns of consumers. Initiatives for bringing scientific knowledge to society through multimedia products may be useful for communicating knowledge related with bioenergy (Redel-Macías et al., 2013).

In summary, conveying knowledge about CE and bioenergy in primary schools, high schools and high education institutions is key for this transition. Besides, the importance of implementing communication strategies in educational activities is key to ensure the efficacy of these actions on all educational levels.

## 2. Definition of constructs and terminologies

To adequately understand the analysis carried out in the research, it must be taken into account that the variables into which the analysed records have been deconstructed (process described in section 3.2) have been obtained from the Descriptor for a Systematic Literature Review on Social Sciences (DESLOCIS) framework published by Gertrudix et al. (2021).

For one thing, the variable called "type of perspective" has two values: (1) "research", which includes publications which have a structure of a research article for use, the objective of which is to present the research results, and (2) "educative/teaching innovation", which refers to the publications which describe interventions or propose models for teaching innovation. The difference between these values lies in both the objective of the research and its formal structure. Therefore, when referring to the type of perspective of the records analysed, the definition of this variable is referred to.

For another thing, in this research, the epistemological perspective is evaluated on the basis of the variable "type of research", which takes into consideration that the selection of methodological instruments determines the epistemological foundation from which, consciously or unconsciously, the authors determine their approach to the object of study, as established, among others, by Gibbons et al. (1994).

## 3. Materials and methods

The research uses two methodological techniques: the systematic literature review (SLR) and qualitative and quantitative synthesis.

As seen in Fig. 1, the systematic literature review is made up of (1) the activity of planning and formulation of the problem, where the research questions are established, (2) the activity of selection of keywords, (3) the extraction through the Publish or Perish tool (Harzing, 2016), and (4) the activity of selection of literature using the PRISMA method. PRISMA stands for Preferred Reporting Items for Systematic

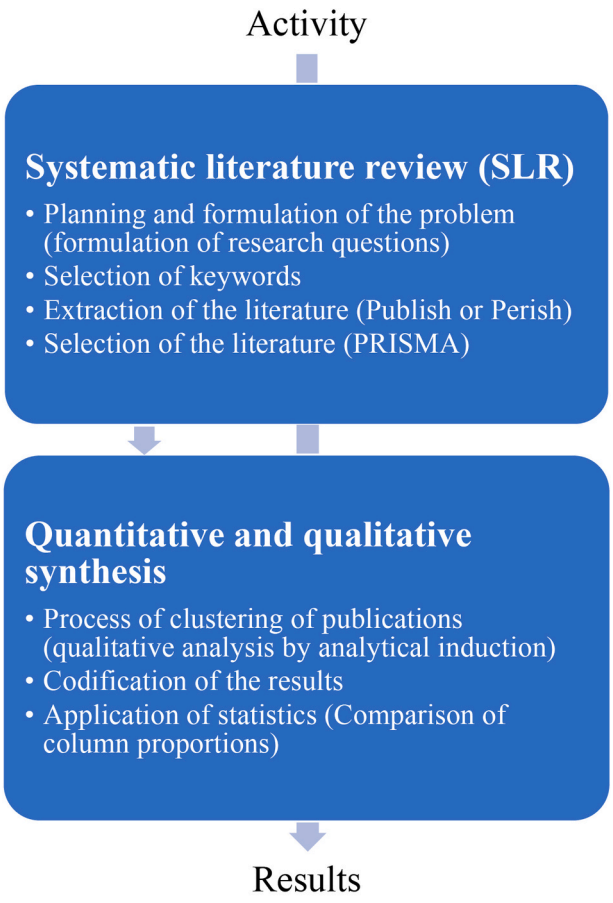


**Fig. 1.** Activity carried out in this research. Diagram based on the methodology used in the research by Fernández-González et al. (2021)

reviews and Meta-Analyses, and is a widely accepted method that provides a 27 items checklist aiming to help researchers develop systematic literature reviews in four phases: Identification, Screening, Eligibility and Included (Liberati et al., 2009).

The qualitative and quantitative analyses is divided between (1) *clustering of publications,* which is carried out through a process of analysis by analytical induction, (2) *the codification of results,* which allows the conversion of the data obtained in the previous stage, and (3) the *quantitative analysis* where statistics are created in order to respond to the review questions.

### 3.1. Systematic literature review

#### 3.1.1. Planning and formulation of the problem

First and foremost, the problem is formulated and the review questions are established to guide the review process (Liberati et al., 2009) towards the quantitative analysis carried out at the end of the research activity.

Then, the issue which motivated the research is posed: the detail of the state of scientific literature related with the fields of education and communication with regard to CE and bioenergy is unknown due to the absence of research which propose a review with this object of study. Additionally, a series of review questions are established, shown in Table 1.

#### 3.1.2. Selection of keywords

Next, keywords are selected using two different methods: a selection process by expert committee and an automated extraction of keywords and subsequent selection.

The expert committee selected the keywords related with CE and

**Table 1**
Association between the objectives and the review questions.

| Associated objective | Research question of the analysis |
|---|---|
| SO1 | (R.Q.1.1) What are the predominant fields of knowledge?<br>(R.Q.1.2) What are the disciplinary approaches in relation with the scope of the object of study? |
| SO2 | (R.Q.2.1) What is the predominant type of research and the epistemological perspective?<br>(R.Q.2.2) Is there a relationship between the type of research (from an epistemological perspective) and the field of knowledge from which the study is approached?<br>(R.Q.2.3) What is the majority perspective (see section 2) from which the analysed studies are approached?<br>(R.Q.2.4) Is there a relationship between the perspective (see section 2) and the scope of the object of study? |
| SO3 | (R.Q.3.1) What is the level of formalisation at a theoretical level that is most present in the publications?<br>(R.Q.3.2) Is there a relationship between the type of perspective (see section 2) and the level of formalisation? |
| SO4 | (R.Q.4.1) Are objectives declared in the research?<br>(R.Q.4.2) In what type of research are objectives declared?<br>(R.Q.4.3) What objectives are predominant in the research? |
| SO5 | (R.Q.5.1) Are hypotheses declared in the research?<br>(R.Q.5.2) Does research with hypotheses have objectives?<br>(R.Q.5.3) To what field of study does research with declared hypotheses belong? |

bioenergy. The committee is composed by the coordinators of the BIOTRES-CM (S2018/EMT-4344) project, financed by the Community of Madrid and the European Development Fund (EDF), that aims to develop new technologies for the processing of biowastes into high value-added bio-based chemicals. The selected terms correspond with those included as keywords in the project proposal: *urban biowastes; circular economy; biorefinery; chemical biobased products; bioenergy.*

The automated extraction, which is used for the selection of words for the areas of communication and education, is divided into two tasks: the identification of journals and the identification of keywords. Each one of these was carried out in duplicate, to obtain the words related with the area of communication and education (see Appendix A):

The first task identified all journals indexed in 2018 on SJCR [https://www.scimagojr.com/] and in 2017 on IJCR [http://incites.clarivate.com/] which belonged to both "communication" and "marketing" categories ("business") on JCR, and those which belonged to "communication" and "education". Then, all articles were extracted (filtered by the last 10 years, from 2009 to 2019) in RIS format, which allowed the identification of all keywords included in these articles using *ENDNote X9.2* program.

The second task consisted of a manual review of each one of the keyword in order to select the final ones though analytical inference. The criteria used by authors in the selection process was that all keyword had to have a connection to the studies of communication and education. This selection included keywords with the same meaning but with different formulations, for example: *eye tracking; eye-tracking.*

As a result, there were 20 keywords related with the area of education selected: *children; education; communication; media literacy; disinformation; distance-learning; e-learning; information technology; technology; internet; learning; research; school; media; social media; social network; student; college students; communication education; learning experiment.* And another 25 were selected for the area of communication: *advertising; communication; communications; media; digital; marketing; effectiveness; engagement; education; higher education; persuasion; memory; credibility; attention; motivation; ux; user experience; experience; eye-tracking; eye tracking; usability; digital content; cross media; transmedia; 360° video.*

#### 3.1.3. Extraction of the literature

Afterwards, a systematic literature extraction was made using the *Harzing's Publish or Perish* version 7 program (Harzing, 2016). The extraction of the literature corresponds with the Identification phase established in the PRISMA model (Moher et al., 2009). A series of boolean operators was created (Table 2) using the keywords obtained through the aforementioned subsection. The searches were carried out in two blocks which cross-referenced the keywords of CE and bioenergy first with education then with communication (Fig. 2). Both were carried out in triplicate in the *Scopus*, Web of Science (WOS) and *Google Scholar* databases. They were chosen because the first two are considered as one of the biggest and most important search systems used by authors, researchers and teachers (Pérez-Escoda, 2017) with more than 34,000 journals in WOS platform and more than 39,000 in Scopus database (Scopus, n.d.), and Google Scholar is considered as the most important supplementary search engine for supporting articles, specially grey literature (Haddaway et al., 2015).

Table 2 shows the relationship of boolean operators and results from the different searches carried out to obtain the articles. 321 items were obtained with the keywords associated with communication, and 230 were obtained with those associated with education: amounting to a total of 551 results.

#### 3.1.4. Selection of literature

After eliminating the duplicates, the subsequent phases of PRISMA model Screening and Eligibility followed, allowing the curating of the sample which would undergo qualitative and quantitative synthesis.

Through automated processes with Microsoft Excel, the existing duplicates were eliminated, resulting in 259 records.

Then, in Screening, the researchers carried out a reading of the titles and abstracts of all results to rule out those whose object of study was not within the scope of education or communication. Therefore, in this phase 3 records were ruled out.

Next, in Eligibility PRISMA phase, the full texts were read by researchers to include only research articles and conference papers published fully in English. In this process, the first two authors individually read all the records and then presented their conclusions to the rest of authors in different group discussions carried out along this phase. This contributed to refine the results of Eligibility PRISMA phase. Hence, 96 records were ruled out.

Consequently, the result reduced the sample to 74 publications in English whose object of study was related with education or communication (see Appendix B). The list of records of each PRISMA phase is available on the database published by Carbonell-Alcocer et al. (2021). Fig. 3 reflects the results obtained from the literature selection process until reaching the figure which makes up the study sample of this research.

### 3.2. Qualitative and quantitative synthesis

Once the full sample was obtained the qualitative and quantitative synthesis followed. It consisted of three activities: the *clustering process*, the *codification of the results* and the *application of statistics* (Fig. 1).

Firstly, in the *clustering process,* researchers read one by one all 74 publications and carried out a qualitative analysis of analytical inference using DESLOCIS model (Gertrudix et al., 2021). DESLOCIS framework was created by authors as a supporting guideline for helping in the process of grouping qualitative content –related to the design, data collection, and analysis of scientific publications– into variables. The variables used for this research are the following and their respective descriptions are detailed in DESLOCIS model: *Type of perspective (see*

**Table 2**
Results of the Identification PRISMA phase carried out with *Publish or Perish*, on the SCPOUS, WOS and Google Scholar databases.

| Boolean operators [Comm] (Searches carried out in July 2019) | Results | | | Boolean operators [Edu] (Searches carried out in April 2020) | Results | | |
|---|---|---|---|---|---|---|---|
| | S | W | GS | | S | W | GS |
| **"urban biowaste"** AND ("advertising" OR "communication" OR "communications" OR "media" OR "digital" OR "marketing" OR "effectiveness" OR "engagement" OR "education" OR "higher education" OR "persuasion" OR "memory" OR "credibility" OR "attention" OR "motivation" OR "ux" OR "user experience" OR "experience" OR eye-tracking OR "eye tracking" OR "usability" OR "digital content" OR "cross media" OR "transmedia" OR ″360° video") | 0 | 0 | 0 | **"urban biowastes"** AND (children OR education OR communication OR media literacy OR disinformation OR distance-learning OR e-learning OR information technology OR technology OR internet OR learning OR research OR school OR media OR social media OR social network OR student OR college students OR communication education OR learning experiment) | 0 | 0 | 0 |
| "circular economy" AND ("advertising" OR "communication" OR "communications" OR "media" OR "digital" OR "marketing" OR "effectiveness" OR "engagement" OR "education" OR "higher education" OR "persuasion" OR "memory" OR "credibility" OR "attention" OR "motivation" OR "ux" OR "user experience" OR "experience" OR eye-tracking OR "eye tracking" OR "usability" OR "digital content" OR "cross media" OR "transmedia" OR ″360° video") | 48 | 36 | 108 | **"circular economy"** AND (children OR education OR communication OR media literacy OR disinformation OR distance-learning OR e-learning OR information technology OR technology OR internet OR learning OR research OR school OR media OR social media OR social network OR student OR college students OR communication education OR learning experiment) | 46 | 31 | 63 |
| "chemical biobased products" AND ("advertising" OR "communication" OR "communications" OR "media" OR "digital" OR "marketing" OR "effectiveness" OR "engagement" OR "education" OR "higher education" OR "persuasion" OR "memory" OR "credibility" OR "attention" OR "motivation" OR "ux" OR "user experience" OR "experience" OR eye-tracking OR "eye tracking" OR "usability" OR "digital content" OR "cross media" OR "transmedia" OR ″360° video") | 0 | 0 | 0 | **"chemical Biobased products"** AND (children OR education OR communication OR media literacy OR disinformation OR distance-learning OR e-learning OR information technology OR technology OR internet OR learning OR research OR school OR media OR social media OR social network OR student OR college students OR communication education OR learning experiment) | 0 | 0 | 0 |
| "bioenergy" AND ("advertising" OR "communication" OR "communications" OR "media" OR "digital" OR "marketing" OR "effectiveness" OR "engagement" OR "education" OR "higher education" OR "persuasion" OR "memory" OR "credibility" OR "attention" OR "motivation" OR "ux" OR "user experience" OR "experience" OR eye-tracking OR "eye tracking" OR "usability" OR "digital content" OR "cross media" OR "transmedia" OR ″360° video") | 41 | 23 | 49 | "bioenergy" AND (children OR education OR communication OR media literacy OR disinformation OR distance-learning OR e-learning OR information technology OR technology OR internet OR learning OR research OR school OR media OR social media OR social network OR student OR college students OR communication education OR learning experiment) | 29 | 17 | 35 |
| "biorefinery" AND ("advertising" OR "communication" OR "communications" OR "media" OR "digital" OR "marketing" OR "effectiveness" OR "engagement" OR "education" OR "higher education" OR "persuasion" OR "memory" OR "credibility" OR "attention" OR "motivation" OR "ux" OR "user experience" OR "experience" OR eye-tracking OR "eye tracking" OR "usability" OR "digital content" OR "cross media" OR "transmedia" OR ″360° video") | 7 | 2 | 7 | "biorefinery" AND (children OR education OR communication OR media literacy OR disinformation OR distance-learning OR e-learning OR information technology OR technology OR internet OR learning OR research OR school OR media OR social media OR social network OR student OR college students OR communication education OR learning experiment) | 13 | 4 | 4 |
| SUM | 96 | 61 | 164 | SUM | 83 | 48 | 99 |
| TOTAL | 321 | | | TOTAL | 230 | | |

*section 2), Scope of the object of study, Field of knowledge approach/-Research Discipline, Type of research, Classification of Objectives, Declaration of Objectives, Declaration of hypothesis, Level of formalisation at a theoretical level: theory/principle/model,* and *Number of Analysis techniques.*

Secondly, in *codification of results* process, a numerical value was applied to each one of the values of the different variables in order to proceed to *the application of statistics*.

Finally, in the *application of statistics* process, a univariable and multivariable qualitative analysis was carried out to answer the review questions. First, the univariable analysis was carried out by analysis of frequencies and vertical percentages. Then, the multivariable analysis was carried out through the tables comparing proportions by column using the Z-test to check the existence of significant statistical difference between the compared percentages (IBM, 2021).

## 4. Results and discussion

This section details the outcomes obtained in the qualitative and quantitative synthesis. For one thing, the result of the *clustering process* and the *codification of results* can be seen in Appendix C. For another, the *applications of the statistics* allowed the review questions presented in Table 1 to be answered and the result are presented below.

Despite the consensus of the scientific community on education (Whalen et al., 2018), and communication (Skjølsvold, 2012) being key aspects to achieve the transformation from a linear economy into a circular economy, the scientific literature addressing the CE and bioenergy from the perspective of education or communication still continues to be limited in scope.

### 4.1. Predominant fields of knowledge in relation with the scope of the study

Firstly, to answer R.Q.1.1 What *are the predominant fields of knowledge?* A percentage count has been carried out of the total 74 records taking into account the "field of knowledge approach" variable (Gertrudix et al., 2021). 40.5% (n = 30) correspond to the field of knowledge of "Engineering and architecture", followed by "Social and Legal Sciences" with 29.7% (n = 22), "Art and Humanities" with 16.2% (n = 12), "Science" with 12.2% (n = 9) and "Health Sciences" with just 1.4% (n = 1).

Next, the analysis which answers R.Q.1.2 What *are the disciplinary*

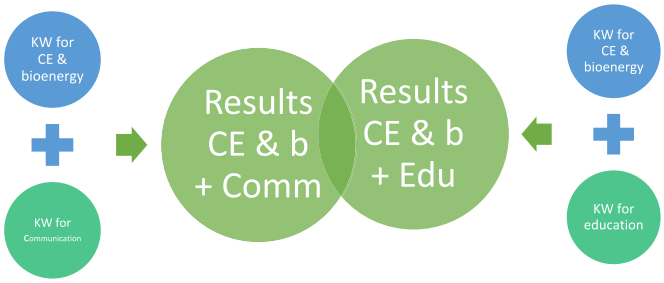


**Fig. 2.** Cross-referencing of keywords related with the two different searches carried out.

*approaches in relation with the scope of the object of study?* Reveals significant differences after undertaking the comparison of "field of knowledge approach" and "scope of the object of study" variables. Firstly, the proportion of "Education" publications whose field is "Engineering and Architecture" or "Art and Humanities" is significantly greater than the proportion of publications of the field "Social and Legal Sciences". Secondly, the proportion of articles of "Public Policies" whose discipline is "Social and Legal Sciences" is greater than for "Engineering and Architecture" and "Art and Humanities". For the disciplines of "Science" and "Health Sciences", the sample base is too small to find significant differences at 95% (Table 3).

With regard to the articles whose scope of the object of study is "Communication", there are no significant differences between the proportions of articles based on their discipline.

The field of knowledge from which this issue is addressed most in the scientific literature analysed is that of engineering, as seen in Ramírez and Ramírez (2015) and Williams I. D. et al. (2018) studies. However, as Mendoza et al., (2019) indicates, it is necessary to implement the CE in higher education institutions, as well as having to promote teaching of related disciplines with sectors beyond the field of engineering (Hall and Velez-Colby, 2018). These results also show that access to scientific knowledge which reflects on education is limited and minimal, as corroborated by Whalen et al. (2018), despite the presence of many practical studies.

Therefore, these outcomes highlight the lack of studies addressing the concept of CE and bioenergy from Social Sciences and Humanities, a field in which the Ellen MacArthur Foundation (Ellen MacArthur Foundation, n.d.), among other entities, bas been working for years. This Foundation has created a large network in which businesses and universities participate in order to promote the principles of the circular economy in research and teaching. Additionally, it offers access to the CE100 Library with scientific articles, case studies and feasibility studies, which reinforce the idea of the importance of scientific knowledge to promote aspects which allow transformation toward the circular economy.

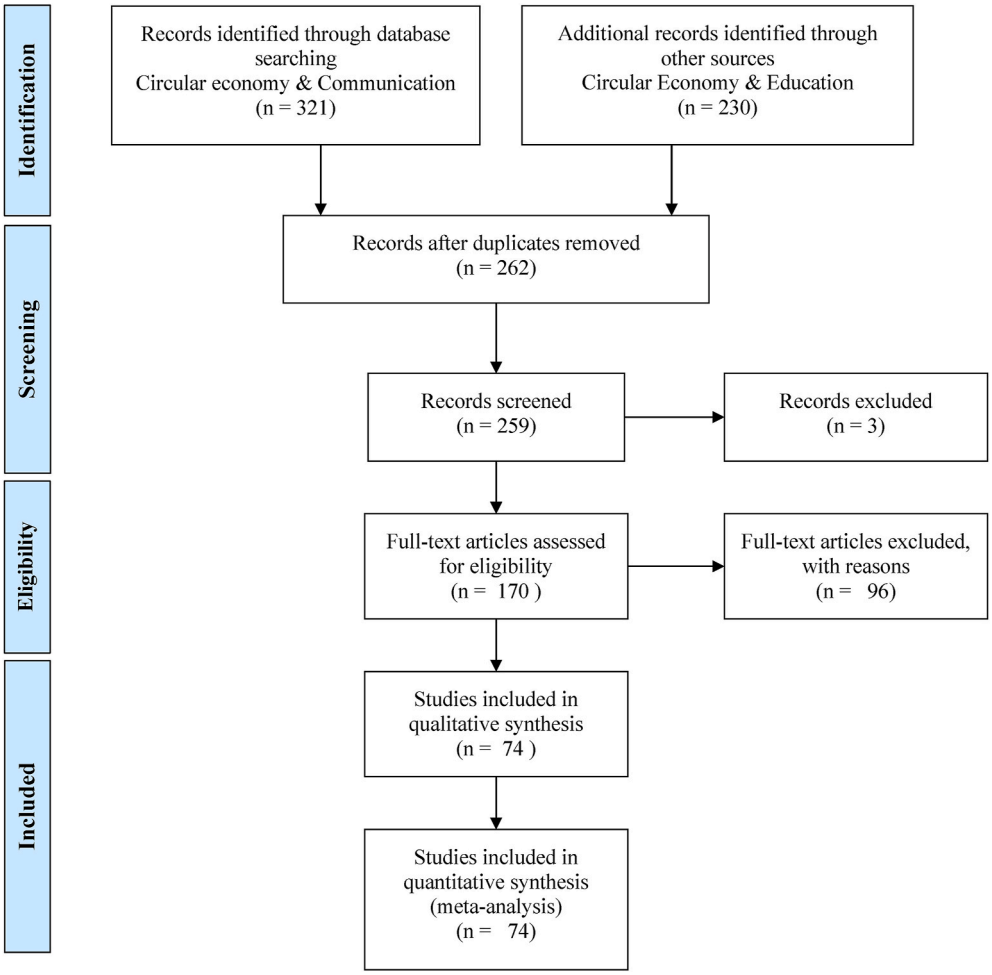


**Fig. 3.** PRISMA flow chart of the literature extraction and selection process. Based on the PRISMA method (Moher et al., 2009).

### 4.2. Types of research and predominant fields of knowledge

For greater detail on the epistemological approach of the analysed research, the "type of research" variable is broken down by frequencies and vertical percentages, describing the type of research based on their nature. An answer is thereby found for R.Q.2.1 What *is the predominant type of research and the epistemological perspective?* The descriptive and analytical research have similar values, with 47.3% (n = 35) and 44.6% (n = 33) respectively. At the end of the list are comparisons with 5.4% (n = 4), participative with 2.7% (n = 2) and explanatory which do not have records.

Therefore, the attention is focused on the two most numerous (descriptive and analytical). When the two analysed variables are compared individually, until now enlightening results are revealed to respond to R.Q.2.2 *Is there a relationship between the type of research (from an epistemological perspective) and the field of knowledge from which the study is approached?* As shown in Table 4, the proportion of descriptive research whose field is "Engineering and Architecture" is significantly more numerous than the proportion of records of "Social and Legal Sciences" and "Art and Humanities". Conversely, with regard to the proportion of analytical research addressed from "Social and Legal Sciences", it is significantly greater than the proportion of publications of "Engineering and Architecture" or "Art and Humanities".

Conclusions on the other fields are not notable due to the small sample, which does not allow significant differences to be identified at 95% with the comparison of proportions by column.

To respond to R.Q.2.3 What *is the majority perspective (see section 2) from which the analysed studies are approached?,* the "type of perspective" variable is analysed (Gertrudix et al., 2021), which divides the analysed records between "research" with 70.3% (n = 52) and "educative/teaching innovation" with 29.7% (n = 22).

If this variable is cross-referenced with the "scope of the object of study", R.Q.2.4 *Is there a relationship between the perspective (see section 2) and the scope of the object of study?* Can be answered. The analysed records which are classified with the value "research" and whose scope of the object of study is encompassed in "public policies" are significantly more numerous than records whose perspective is "educative/teaching innovation". Conversely, the number of records of the latter perspective with a field of study in "education" are significantly greater than those which belong to the "research" perspective type according to the comparison of proportions by column. No significant differences are observed in the records which belong to the field of "communication" (Table 5).

With regard to the type of research, the results show that descriptive and analytical research is predominant. The importance of in-depth knowledge of a phenomenon involves analysis and understanding of the opinion of students (López-Mosquera et al., 2015), as well as the tools which may help to understand the behaviour of users and thereby be able to improve the messages used to communicate concepts of the CE (Uren et al., 2016). The lack of analytical studies limits the in-depth knowledge of the object of study of education or communication with regard to the CE or bioenergy, which limits the design of actions which may be carried out.

### 4.3. Level of formalisation at a theoretical level

By analysing the level of formalisation at a theoretical level, R.Q.3.1. is answered. Thus, 89.2% (n = 66) of the records analysed explicitly mention theories, principles or models. If the values are broken down individually, it is observed that 45.9% (n = 34) of the records explicitly mention theories, 43.2% (n = 32) mention principles, and 56.8% (n = 42) mention models.

If this variable is cross-referenced, by comparison of proportions by column, with the "type of perspective", it is observed that there are not significant differences at 95%, which indicates that there is no *relationship between the type of perspective and the level of formalisation* (R.Q.3.2).

### 4.4. Declaration of objectives and purpose of research

In order to answer R.Q.4.1 *Are objectives declared in the research?*, the results obtained from the "declaration of objectives" variable are observed. The results reveal that 79.7% (n = 59) of the total publications analysed explicitly declare the objectives of the research, with 20.3% (n = 15) not declaring them.

With this data, it is ascertained in what type of research objectives are declared (R.Q.4.2). The comparison of proportions by column of the "declaration of objectives" and "type of research" variables reveal interesting, although not statistically conclusive results due to the small sample that has been obtained from the records classified as comparative and participative. As observed in Table 6, 71.4 % (n = 25) of the descriptive research declares objectives. In the same way, 84.8% (n = 28) of the analytical research declares objectives.

For greater detail on the declaration of objectives of research, the "classification of objectives" variable has been broken down. This variable considers up to three simultaneous values in a single record, which means that research may have registered one, two or three purposes at the same time. Therefore, the values of the vertical percentages are shown (Fig. 4) for a broader perspective of the purpose and to thereby answer R.Q.4.3 What *objectives are predominant in the research?* The predominant values are "analyse" (44.6%), "describe" (44.6%), "establish" (33.8%), "detail" (29.7%) and "deconstruct" (23%).

Two main groups of articles are found based on the purpose of the research. Firstly, a clear predisposition is noted for publishing studies which seek to describe, detail or define a phenomenon related with education or communication which transversally address the circular economy or bioenergy. In this group of studies, more theoretical works are found. Secondly, there is the group of studies which analyse,

**Table 3**
Comparison of proportions by column of "field of knowledge approach" and "scope of the object of study" variables.

| vertical % | | | Field of knowledge from which the study is addressed | | | | |
|---|---|---|---|---|---|---|---|
| | | **Total** | (A) Engineering and Architecture | (B) Social and Legal Sciences | (C) Art and Humanities | (D) Science | (E) Health Sciences |
| | **Sample base** | **74** | **30** | **22** | **12** | **9**[b] | **1**[b] |
| Scope of the object of study | Communication | **24.3** | 20 | 31.8 | 8.3 | 33.3 | 100 |
| | Education | **60.8** | 76.7 BE[a] | 31.8 | 83.3 BE[a] | 55.6 E | 0 |
| | Public Policies | **14.9** | 3.3 | 36.4 ACE[a] | 8.3 | 11.1 | 0 |

[a] Most significant differences at 95%.
[b] Sample base too small.

**Table 4**
Comparison of proportions by column of the "field of knowledge" and "type of research" variables.

| vertical % | | | Field of knowledge from which the study is addressed | | | | |
|---|---|---|---|---|---|---|---|
| | | **Total** | (A) Engineering and Architecture | (B) Social and Legal Sciences | (C) Art and Humanities | (D) Science | (E) Health Sciences |
| | **Sample base** | **74** | **30** | **22** | **12** | **9**[b] | **1**[b] |
| Type of research | Descriptive | **47.3** | 63.3 BCE[a] | 18.2 | 58.3 | 44.4 | 100 |
| | Analytical | **44.6** | 26.7 | 72.7 ACD[a] | 33.3 | 55.6 | 0 |
| | Comparative | **5.4** | 3.3 | 9.1 | 8.3 | 0 | 0 |
| | Participative | **2.7** | 6.7 | 0 | 0 | 0 | 0 |
| | Explanatory | **0** | 0 | 0 | 0 | 0 | 0 |

[a] Most significant differences at 95%.
[b] Sample base too small.

**Table 5**
Comparison of proportions by column of the "scope of the object of study" and "type of perspective" variables.

| vertical % | | | Type of perspective | |
|---|---|---|---|---|
| | | **Total** | (A) Research | (B) Educative/ teaching innovation |
| | **Sample base** | **74** | **52** | **22** |
| Scope of the object of study | Communication | **24.3** | 28.8 | 13.6 |
| | Education | **60.8** | 50 | 86.4 A[a] |
| | Public policies | **14.9** | 21.2 B[a] | 0 |

[a] Most significant differences at 95%.

establish or deconstruct the phenomenon. Here more innovative articles and conference papers appear, which go beyond the description of the phenomenon and propose solutions oriented toward processes of transformation and change of model.

### 4.5. Declaration of hypothesis

Analysis of the variable associated with R.Q.5. *Are hypotheses declared in the research?* shows that 86.5% (n = 64) declare hypotheses, with 13.5% (n = 10) of records not declaring them explicitly.

By cross-referencing this variable ("declaration of hypothesis") with that of "declaration of objectives", R.Q.5.2 *Does research with hypotheses have objectives?* is answered. The comparison of proportions by column demonstrates the absence of significant differences between the proportions of studies which declare objectives and those which declare hypotheses. Therefore, it cannot be stated that studies which declare hypotheses necessarily declare objectives.

Conversely, significant differences are found between the proportions by column when the "scope of the object of study" and "declaration of hypothesis" are compared, in order to respond to R.Q.5.3 *To what field of study does research with declared hypotheses belong?* As shown in Table 7, no record classified in "communication" is found to declare a hypothesis. In records whose field of study is "education" or "public policies", there are no significant differences at 95%.

No relationship is found between the declaration of objectives and hypotheses, although the difference existing between education and communication studies in declaration of hypotheses is notable, indicating greater formalisation in the case of the former.

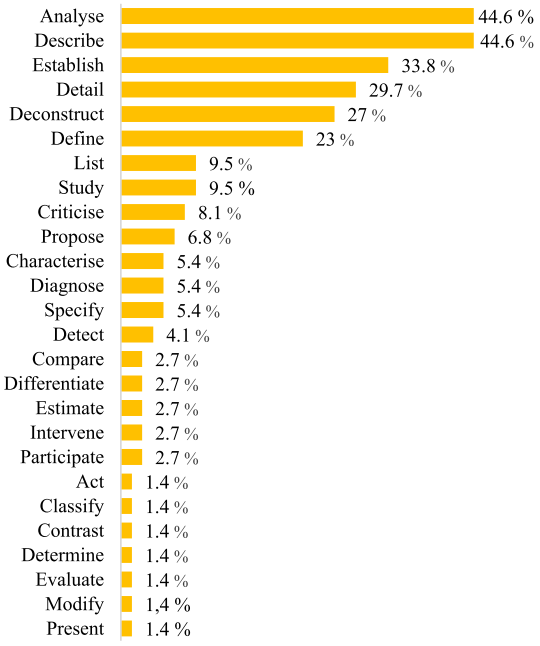


**Fig. 4.** Classification of the objectives of research. Multiple choice "classification of objectives" variable.

**Table 6**
Comparison of proportions by column of the "declaration of objectives" and "type of research" variables.

| vertical % | | | Type of research | | | | |
|---|---|---|---|---|---|---|---|
| | | **Total** | (A) Descriptive | (B) Analytical | (C) Comparative | (D) Participative | (E) Explanatory |
| | **Sample base** | **74** | **35** | **33** | **4**[b] | **2**[b] | **0**[b] |
| Declaration of objectives | Objectives are declared | **79.7** | 71.4 | 84.8 | 100.0 AB | 100.0 AB | 0 |
| | Objectives are not declared | **20.3** | 28.6 CD[a] | 15.2 CD[a] | 0 | 0 | 0 |

[a] Most significant differences at 95%.
[b] Sample base too small.

**Table 7**
Comparison of proportions by column of the "field of study" and "declaration of hypothesis" variables.

| vertical % | **Sample base** | | Declaration of hypothesis | |
|---|---|---|---|---|
| | | **Total** | (A) Hypothesis are declared | (B) Hypothesis are not declared |
| | | **74** | **10** | **64** |
| Scope of the object of study | Communication | **24.3** | 0 | 28.1 A[a] |
| | Education | **60.8** | 80 | 57.8 |
| | Public Policies | **14.9** | 20 | 14.1 |

[a] Most significant differences at 95%.

## 5. Conclusions

As established in the PO, authors conclude that the scientific literature that addresses CE and bioenergy from education and communication areas is limited in scope and still in an initial phase, and, thus, the level of maturity is considered low. Besides, the current analysis allowed to discover new aspects of the object of study. Although there are still more characteristics to be known, this research will permit the academy to act consequently in regard to creation of CE an bioenergy literature address from education and communication.

SH1 establishes that *Social Sciences are the predominant discipline from which the object of study is addressed* and authors refute it. The field of engineering is addressing CE and bioenergy mainly from education, which denotes the traditional concern and awareness of the sector. Although less numerous, the studies carried out from the field of Art and Humanities also have a high percentage of publications close to the field of education, which shows that the first steps are being taken to address the CE and bioenergy from a field more related to education. Publications whose field of study is communication are fewer in number and are not approaching the issue from the field of Social and Legal Sciences which reveals and demonstrates the urgent need for research on the CE and bioenergy addressed from the perspective of Social Sciences.

With regard to the epistemological approach of published research, SH2.1 that reads *the predominant epistemological approach is descriptive because studies superficially address the object of study* is refuted because even though descriptive studies are prevailing, analytical research is also predominant. In addition, SH2.2 that claimed that *"educative/teaching innovation" studies are predominant* is refuted. Descriptive studies are predominant in research where the field of knowledge is engineering. The majority document educational interventions, although with a lack of detail in addressing the object of study, as they are mainly based on the description of elements of the educational activity carried out from a perspective of educative/teaching innovation. Additionally, analytical studies, which offer more in-depth knowledge of the object of study, are those linked with the field of Social and Legal Sciences. A significant association is not found between the articles which address it from a perspective of research and studies whose field of study is communication, which explains that the latter are not necessarily analytical, despite having an approach from the perspective of research.

SH3 is confirmed, which means that the level of theoretical and methodological formalisation of research gathered in the analysed literature is low. Consequently, our epistemological approach reveals many instances of teaching innovation and concrete learning experiences cases. Although most of these studies pose a hypothetical-deductive structure, they are limited in number and scope, which would be another indicator of research in this field being in an initial stage.

In relation to objectives and hypotheses of research, SH4 –*the majority of studies explicitly declare objectives and have the objective of describing and detailing*– is confirmed and SH5 –*the majority of studies do not explicitly declare the hypotheses*– is refused. Most of publications explicitly declare objectives as well as hypotheses.

## 6. Limitations and future research agenda

This study shows the results of a systematic literature review using the PRISMA method and providing a qualitative and quantitative analysis to explore the level of formalisation at a theoretical and formal level, as well as identifying the areas from which research on the CE and bioenergy are addressed from communication and education. Nevertheless, in undertaking the research, some limitations were found. The first was that the selection of references was restricted to a period of 10 years and to the referenced databases. Conclusions could have been drown differently if the period had been widened. The second was that the selected sample did not have sufficient records to undertake some multivariable analyses, which limited the scope of some results.

These limitations encourage the undertaking of new research which will require broadening the study sample in both number and in the examination of other source documents through a Desk Research process. Additionally, the conclusions presented call for quality studies on the CE and bioenergy to be carried out from the fields of knowledge of Social Sciences and Humanities to transversally address aspects which have to do with communication and education, thereby continuing to elaborate on this field.

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## CRediT authorship contribution statement

**Juan Romero-Luis:** Writing – original draft, Data curation, Investigation, Methodology, Visualization, Resources. **Alejandro Carbonell-Alcocer:** Writing – review & editing, Data curation, Investigation, Methodology, Resources. **Manuel Gertrudix:** Writing – review & editing, Conceptualization, Funding acquisition, Project administration, Supervision, Methodology, Validation. **María del Carmen Gertrudis Casado:** Writing – review & editing, Supervision, Validation.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A

Selection process of keywords for the areas of Communication and of Education.

| Area for which the keywords are obtained | DB | Journal search parameters | Number of journals* indexed | Journal results between the two categories (SJC and JCR) | Total number of articles from all journals (2009-June 2019) | Number of keywords obtained from the articles | Keywords selected by the researchers |
|---|---|---|---|---|---|---|---|
| Education | SJCR | Subject Area: Social Sciences<br>Subject Category: Education<br>All region/Countries<br>Type: All types*<br>Year: 2018<br>Subject Area: Social Sciences<br>Subject Categ.: Communication<br>All region/Countries<br>Type: All types*<br>Year: 2018 | 1222 results<br>411 results | *Applied Environmental Education and Communication*<br>*Art, Design & Communication in Higher Education*<br>*Asia Pacific Media Educator*<br>*Asian Journal of Communication*<br>*Communication Education*<br>*Communication Reports*<br>*Communication Teacher*<br>*Comunicar*<br>*Educational Media International*<br>*Human Communication Research*<br>*Informatics in Education*<br>*Interface: Comunicacao, Saude, Educacao*<br>*International Journal of Distance Education Technologies*<br>*International Journal of Information and Learning Technology*<br>*International Journal of Science Education, Part B: Communication and Public Engagement*<br>*International Journal of Web Based Communities*<br>*Internet and Higher Education*<br>*Journal of Computer Information Systems*<br>*Journal of Empirical Research on Human Research Ethics*<br>*Journal of Media Practice*<br>*Journal of Social and Personal Relationships*<br>*Journalism and Mass Communication Educator*<br>*Learning Environments Research*<br>*Logos (Netherlands)*<br>*New Review of Information Networking*<br>*Online Learning Journal*<br>*Psychology of Language and Communication*<br>*Public Understanding of Science*<br>*Quarterly Journal of Speech*<br>*Qwerty*<br>*South African Computer Journal*<br>*Symbolic Interaction*<br>*Technical Communication Quarterly*<br>*Technology, Pedagogy and Information*<br>*Texto Livre*<br>*Visitor Studies*<br>*Visual Communication* | 8307 articles (of which 8296 articles have keywords) | 65,532 keywords (23,264 unique values) | children<br>education<br>communication<br>media literacy<br>disinformation<br>distance-learning<br>e-learning<br>information<br>technology<br>technology<br>internet<br>learning<br>research<br>school<br>media<br>social media<br>social network<br>student<br>college students<br>communication<br>education<br>learning experiment |

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| Area for which the keywords are obtained | DB | Journal search parameters | Number of journals* indexed | Journal results between the two categories (SJC and JCR) | Total number of articles from all journals (2009-June 2019) | Number of keywords obtained from the articles | Keywords selected by the researchers |
|---|---|---|---|---|---|---|---|
| | | | | *Journal of Business and Technical Communication* | | | digital content<br>cross media<br>transmedia<br>360° video |

* In the case of the SJCR search, it was carried out differently for the area of "Education" than for "Communication". In the former, the search was carried out without filtering the type, and in the latter, the "Journal" type was filtered directly. In the first case, the filtering was carried out subsequently; therefore in both cases, the result reflects only scientific journals.

## Appendix B. List of articles and conference papers analysed

| Title | Authors | Year |
|---|---|---|
| 'All they do is win': Lessons learned from use of a serious game for Circular Economy education | K.A. Whalen, C. Berlin, J.Ekberg, I.Barletta, P. Hammersberg | 2018 |
| "3G" Business Model for Marketing 4.0: Implications for Circular Economy | B. Vassileva, Y. Ivanov | 2017 |
| A case study approach to introduce circular economy in sustainable design education | I. Esparragoza, J. Mesa-Cogollo | 2019 |
| A framework for pairing circular economy and the internet of things | I. Askoxylakis | 2018 |
| A methodological framework for the implementation of circular economy thinking in higher education institutions: Towards sustainable campus management | J.M.F. Mendoza, A. Gallego-Schmid, A. Azapagic | 2019 |
| A Structural Equation Modeling to Explain School Students Intentions to Use Bioenergy: An Indian Case | P. Halder | 2016 |
| Advanced education and training in bioenergy in Europe | I.I. Watkinson, A.V. Bridgwater, C. Luxmore | 2012 |
| AMFI's Reality School: A circular economy agenda for fashion education | N. Hall, F. Velez-Colby | 2018 |
| Analysis on green hotel marketing management under the background of circular economy | X. Song | 2013 |
| Applying circular economy thinking to industry by integrating education and research activities | I.D. Williams, K.P. Roberts, P.J. Shaw, B. Cleasby | 2018 |
| Based on Circular Economy in the Automotive Industry to Implement Green Marketing Research | T. Yuhong | 2012 |
| Bioenergy Academy for Teachers (BEAT) Promotes Multidisciplinary Content in STEM Education | M. Mitra | 2015 |
| Bioenergy Education and Training for the Youth - Does it Matter for the Sustainability of Bioenergy? | P. Halder | 2014 |
| Bioenergy experts and their imagined "obligatory publics" in the United States: Implications for public engagement and participation | W.M. Eaton, M. Burnham, C.C. Hinrichs, T. Selfa | 2017 |
| Biorefinery Education as a Tool for Teaching Sustainable Development | A. Jääskeläinen, E. Hakalehto | 2018 |
| Biorefinery Virtual Lab-Integrating E-learning Techniques and Theoretical Learning | M. D. Redel-Macias, S. Pinzi, A. J. Cubero-Atienza, M. P. Dorado, M. P. Martinez-Jimenez | 2013 |
| Building a business case for implementation of a circular economy in higher education institutions | J.M.E. Mendoza, A. Gallego-Schmid, A. Azapagic | 2019 |
| Circular Design Project – Open Knowledge Co-creation for Circular Economy Education | A. Obiols Sales, A. De Eyto, M. McMahon, A. Jimenez Higueras, Y. Bakirlioglu, J. Segalàs Coral, G. Tejedor Papell, B. Lazzarini, M. Crul, P. Joore, R. Wever, N. Ozkan | 2019 |
| Circular economy action programs and countermeasures for small and medium-sized resource-based cities of China-case study of Zibo City of Shandong Province | Q. Ren | 2011 |
| Circular economy and behaviour change: Using persuasive communication to encourage pro-circular behaviours towards the purchase of remanufactured refrigeration equipment | Z. Muranko, D. Andrews, I. Chaer, E.J. Newton | 2019 |
| Circular Economy as an important subject of environmental education in the era of energy demand | A. Kluczkowski, M. Wyrostkiewicz | 2018 |
| Circular Economy in Higher Education Institutions: Lessons Learned From Brazil-Colombia Network | U. Maruyama, P. Martinez Sanchez, A. Monteiro Guimaraes Trigo, W.H. Motta | 2019 |
| Circular Economy in integrated production development education | M. Lanz, H. Nylund, T. Lehtonen, T. Juuti, K. Rättyä | 2019 |
| Communication as a prevention tool: A key lever for general acceptance of the role of incineration (waste-to-energy) and transformation plants towards circular economy | L. Strano | 2019 |
| Comparing industry and academia priorities in bioenergy education: a Delphi study | K. Grzyb, B.D. Hartman, K.G. Field | 2018 |
| Curb your enthusiasm: On media communication of bioenergy and the role of the news media in technology diffusion | T.M. Skjolsvold | 2012 |
| Dealing with societal challenges of a circular economy in engineering education | V. Cappuyns, T. Stough | 2016 |
| Decomposing the Complexity of Value: Integration of Digital Transformation of Education with Circular Economy Transition | S. Türkeli, M. Schophuizen | 2019 |
| Developing Adequate Communication of Waste Footprints of Products for a Circular Economy—A Stakeholder Consultation | R. Laurenti, M. Martin, A. Stenmarck | 2018 |
| Digitalizing the Circular Economy | M. Reuter | 2016 |
| Eco-cities in the paradigm of a circular economy and a comprehensive internet | E. Rudskaya | 2019 |
| Eco-innovation and firm growth in the circular economy: Evidence from European small- and medium-sized enterprises | P. Demirel | 2019 |
| Econometric model for measuring the impact of the education level of the population on the recycling rate in a circular economy. | C. Pelau, A.C. Chinie | 2018 |
| | L. Rodríguez | 2019 |

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| Title | Authors | Year |
|---|---|---|
| Education + Industry 4.0: Developing a Web Platform for the Management and Inference of Information Based on Machine Learning for a Hydrogen Production Biorefinery | | |
| Education and Communications within the Circular Economy, the Internet of Things, and the Third Industrial Revolution. Challenges ahead the"Competency based" Education Model | T. Purcarea | 2014 |
| Engaging Minority Students in Sustainable Bioenergy and Water Quality through an Education and Research Network | K. Castillo | 2016 |
| Entrepreneurship Education as a method of stimulating bioenergy Ventures and technology transfer: a propotional model | M.G. Kenney, D.M. Daniels, N.M. Khanfar | 2013 |
| Green-washing or best-case practices? Using circular economy and Cradle to Cradle studies in business education. | H. Kopnina | 2019 |
| Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers | V. Rizos | 2016 |
| Integrated circular economy and education model to address aspects of an energy-water-food nexus in a dairy facility and local contexts | S. Kilkis, B. Kilkis | 2017 |
| Interactive posters: A valuable means of enhancing communication and learning about productive paths toward sustainable bioenergy | V.H. Dale, K.L. Kline | 2017 |
| Interdisciplinary circular economy design education through local and regional partnerships | M. Williams, M. McDonough, S. Edge | 2017 |
| Is it possible to change from a linear to a circular economy? An overview of opportunities and barriers for European small and medium-sized enterprise companies | C. Garcés-Ayerbe | 2019 |
| KATCH_e: Introducing circular economy into higher- education design curricula. Overview of the training needs, state of the art | l. Celades, T. Ros, C. Rocha , D. Camocho, K. Schmidt, R. Pamminger , S. Schmidt, M. Kalleitner-Huber , S. Veral, L. Ruiz, E. Mulet, V. Chulvi | 2017 |
| Key elements in assessing circular economy implementation in small and medium-sized enterprises | V. Prieto-Sandoval | 2018 |
| Key strategies, resources, and capabilities for implementing circular economy in industrial small and medium enterprises | V. Prieto-Sandoval | 2019 |
| Making practical experience: Teaching thermodynamics, ethics and sustainable development with PBL at a bioenergy plant | D.C. Ramirez | 2015 |
| Making Sustainable Biofuels and Sunscreen from Corncobs to Introduce Students to Integrated Biorefinery Concepts and Techniques | H. Zhou, W. Zhan, L. Wang, L. Guo, Y. Liu | 2018 |
| Mapping circular economy activities in the European Union: Patterns of implementation and their correlates in small and medium-sized enterprises | T. Katz-Gerro | 2019 |
| Marketing Approaches for a Circular Economy: Using Design Frameworks to Interpret Online Communications | L. Chamberlin, C. Boks | 2018 |
| Methodological frameworks of marketing research in the bioenergy market | J. Galchynska | 2017 |
| Non-technical success factors for bioenergy projects—Learning from a multiple case study in Japan | Y.B. Blumer, M. Stauffacher, D.J. Lang, K. Hayashi, S. Uchida | 2013 |
| Perceptions of energy production from forest biomass among school students in Finland: Directions for the future bioenergy policies | P. Halder | 2014 |
| Promotion of Student's Abilities in Proper Judgment on the Topic of Bio-energy: Development of Lesson Model in Chemical Education | H Fujii, H Ogawa, R Utsumi, ... | 2009 |
| Public education for environmental consciousness and the government's role for a circular economy the German case | E Akcaoglu, R Wehner | 2017 |
| Re-design of a Digital Voice Recorder to meet the needs of Circular Economy - Status Analysis | Rainer Pamminger, D.I. Stefan Kuso, Wolfgang Wimmer, Gerhard Podhardsky | 2016 |
| Recommendations for Independently-owned Vancouver Cafés to Achieve Zero Waste Targets | H Saito | 2016 |
| Reflections on service learning for a circular economy project in a Guatemalan Neighborhood, Central America | P.A. Kumble | 2019 |
| Review of Security and Privacy for the Internet of Medical Things (IoMT). Resolving the protection concerns for the novel circular economy bioinformatics | G. Hatzivasilis, O. Soultatos, S. Ioannidis, C. Verikoukis, G. Demetriou, C.I. Tsatsoulis | 2019 |
| Scientific literature analysis on big data and internet of things applications on circular economy: a bibliometric study | G.C. Nobre, E. Tavares | 2017 |
| Seeing the forest and not the trees: Learning from nature's circular economy | W.L. Tate, L. Bals, C. Bals, K. Foerstl | 2019 |
| Social media and sentiment in bioenergy consultation | V. Uren, D. Wright, J. Scott, Y. He, H. Saif | 2016 |
| Study for Innovative Contents of Accounting Professional Education in Circular Economy | E. Li, G. Li, G. Li | 2019 |
| Study on circular economy education in rural areas in China | P. Guo, X. Zhang | 2014 |
| Subject knowledge and perceptions of bioenergy among school teachers in India: Results from a survey | P. Halder, S. Havu-Nuutinen, J. Pietarinen, A. Zyadin, P. Pelkonen | 2014 |
| The circular economy concept in design education: Enhancing understanding and innovation by means of situated learning | A. Wandl, V. Balz, L. Qu, C. Furlan, G. Arciniegas, U. Hackauf | 2019 |
| The circular economy fashion communication canvas | S.L. Han, C.E. Henninger, J. Blanco-Velo, P. Apeagyei, D.J. Tyler | 2017 |
| The circular economy, design thinking and education for sustainability | D. Andrews | 2015 |
| The development of a bioenergy-based green chemistry curriculum for high schools | C. Kohn | 2019 |
| The high school students' perceptions and attitudes toward bioenergy | S. Özbaş | 2016 |
| The hotspots of life cycle assessment for bioenergy A review by social network analysis | J. Li, Y. Wang, B. Yan | 2018 |
| The Theory of Planned Behavior model and students' intentions to use bioenergy: A cross-cultural perspective | P. Halder | 2016 |
| Towards an Education for the Circular Economy (ECE): Five Teaching Principles and a Case Study | J Kirchherr, L Piscicelli | 2019 |
| Understanding sustainability and the circular economy through flipped classroom and challenge-based learning: an innovative experience in engineering education in Spain | J. Rodriguez-Chueca, A. Molina-Garcia, C. Garcia-Aranda, J. Perez, E. Rodriguez | 2019 |

## Appendix C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2021.129007.

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