This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TLT.2021.3073559, IEEE Transactions on Learning Technologies

The State of the Art on Collective Intelligence in Online Educational Technologies

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***Abstract*—The application of the collective intelligence (CI) concept has yielded significant results in many knowledge areas and it has substantial potential to yield results in the educational context. In view of distance education and online educational technologies, the use of CI has enormous potential to improve collaboration, social learning, and problem solving. However, there is still not a clear understanding of how CI has been used in combination with online educational technologies, due to a lack of secondary studies in this context. Thus, we conducted a systematic literature review with the objectives of determining how CI has been used in online learning environments and identifying the benefits and/or the difficulties that are encountered in the process of its use. We have analyzed 354 studies and only 30 have met our inclusion criteria. The main contributions to online learning of these 30 studies were categorized and discussed. Our results have shown that CI enables the exploration of the potential of collaboration and collaborative learning in social environments to create more diverse educational contents and to improve educational aspects using group intelligence. Moreover, approximately 74% of the studies presented positive evidence of learning benefits. However, approximately 40% of the studies also presented positive evidence of implementation difficulties. These and other results presented in this paper demonstrate that more research is necessary to explore the potential of CI in online learning technologies.**

***Index Terms*—collective intelligence, systematic literature review, online educational technologies, social learning, collaboration.**

I. Introduction

COLLECTIVE intelligence (CI) is a broad and multidisciplinary concept that has been identified in studies in diverse knowledge fields over many years [1]. Broadly, CI is a form of universally distributed intelligence that is incessantly valued, coordinated in real time and results in the effective mobilization of skills [2]. However, the concept of CI has been updated in recent years due to the emergence of new computational technologies [1], especially as new tools that support collaboration have become available [3]. Now, CI is related to engagement in intellectual cooperation of human groups to create, innovate and invent [4], [5] and to perform a wide variety of tasks [6]. Integrating these definitions, we can conceptualize CI as the ability of a group of individuals to perform a variety of tasks of creation, innovation and invention through the intellectual cooperation of its members.

CI emerges from the collaboration and competition of many individuals [2], [3], [7] and is enhanced by the use of computational technologies, which enable users to share their ideas with others quickly, easily, and safely [8]. Technologies that promote CI of groups include discussion forums, blogs, and wikis [9]. Examples of the use of CI are the construction of a collective knowledge base of the entire web by Google using the judgements of millions of people to produce intelligent answers to searches [10], the creation and maintenance of the world's largest encyclopedia by volunteers of Wikipedia [10], the digitization of old books word by word by reCAPTCHA users [11] and Duolingo, which aims at translating the entire web using the people who wish to learn a foreign language [12]. In all of these examples, a group of individuals is using their skills to perform complex tasks and enabling the construction of universally distributed knowledge through of the support of technologies.

In this paper, we focus only on online educational technologies. Online educational technologies have revolutionized the way education can be delivered [13] by allowing online courses to be made available to thousands of students around the world. Educational technologies that are on the rise include course management systems (CMSs), such as Moodle; intelligent tutoring systems (ITSs) [14], [15]; computer-supported collaborative learning (CSCL) [16], [17]; and massive open online courses (MOOCs) [18], such as edX, Coursera, and Udacity courses. In view of online educational technologies, the use of CI has enormous potential to improve collaboration, social learning, and the resolution of complex problems. In these technologies, CI presents the possibility of permanent and collaborative learning by guiding students in the knowledge acquisition process [4].

The use of CI has yielded significant results in many knowledge areas and it has substantial potential to yield results in the educational context [19]. Even though CI is not a new concept, its combination with online educational technologies is an emerging area [4], [5], [20]. Several studies have shown that CI has positive impacts in the educational field [4], [21]–[24], and evidence of the advantages of CI in distance learning has been presented [25]. Although studies highlight the huge potential of CI for education [3], [26], there is still no clear understanding of how CI has been used together with the online educational technologies due to a lack of secondary

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001 and in part by Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) (*Corresponding author: Thyago Tenório.*)

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studies in this context.

Thus, a systematic literature review (SLR) [27] with the objective of investigating and understanding how CI has been used within online educational technologies was conducted, which provided a new broad view of the use of CI in online educational technologies by analysing primary studies in the literature. The main research question (RQ) is the following: **How has CI been used in online educational technologies?** As a secondary objective, the SLR aims at investigating the evidence of the benefits and/or difficulties that are encountered in the process of using CI along with these technologies.

This article is organized into five sections: The current section, namely, Section I, introduces the proposed work. Section II describes the developed protocol and performed execution process of the SRL. Section III provides an overview of the obtained data. Section IV discusses in detail the main findings of this study. Finally, Section V presents the conclusions of this study and discusses potential future research directions.

II. Protocol Definition and Execution of the SRL

To develop this study, we conducted a SLR, which is a form of secondary study that uses a well-defined methodology to identify, analyse, and interpret all available evidence regarding a RQ in an unbiased and repeatable manner [27]. The main reason for choosing to conduct an SLR is that the entire process follows a predefined methodology, thereby avoiding bias and enabling replication. Researchers seek to analyse studies that have been published in the literature that are related and unrelated to their RQs [28]. Our SLR followed the guidelines that were presented by [27] and used templates from a previous SLR that was conducted by the authors, which provided increased agility in the review process.

The guidelines indicate steps to follow to conduct a satisfactory SLR. **The first step is to create a document, which is called a protocol**, that contains all the necessary information for guiding the execution process of the SLR, such as the objectives, RQs, keywords and their synonyms, search string, databases, selection criteria (inclusion, exclusion, and quality), extraction form, and search process [28]. This section briefly presents the developed protocol for this SLR.

The main objective of the SLR is to investigate and determine how CI has been used within online educational technologies **to provide an overview of the use of CI in online educational technologies**. This investigation seeks to answer the following RQ: **How has CI been used in online educational technologies?** Based on this RQ, our main objectives are to analyse why and for what CI has been used within educational technologies and to search for evidence of benefits of its use. The difficulties that are encountered in the process will also be described by this review. Finding CI common usage patterns within educational technologies can help us map the various fields in which this concept can be applied.

Based on the predefined objectives of the SLR, we defined the RQs, which are presented in Table I. For each question, we describe the motivation for creating it and the objective on which it is based. RQ1 corresponds to the main objective of the SLR, while questions RQ2 and RQ3 correspond to the secondary objectives.

Next, we defined a search string, which represents the text that is used to search studies in digital libraries. For this, we defined the keywords and their synonyms. Since CI is a broad concept and is implemented in several ways with respect to computational technologies, we used the definition that is presented in [29] to compose the related keywords. CI encompasses the concepts of human computation, crowdsourcing, social computing [29] and their synonyms. In addition, we would like to limit the application context for online educational technologies. Thus, a second group of keywords refer to the most well-known educational technologies today. This group was presented by [28]. The keywords (and synonyms) for this SLR, which were adapted from [28], were as follows:

- **G1- CI (1)**: Human Computation (2), Human-based computation (3), Human-assisted computation (4), Ubiquitous Human Computing (5), Distributed Thinking (6), Crowdsourcing (7), Social Computing (8)
- **G2- Online Learning Environment (9)**: Learning Management System (10), LMS (11), Online Education (12), Collaborative Learning (13), CSCL (14), Intelligent Tutoring System (15), Intelligent Educational System (16), Massive Open Online Course (17), MOOC (18), Adaptive Educational System (19), Adaptive Learning System (20)

The keywords are separated into two groups (G1 and G2). Group G1 consists of words that are related to the term *CI* and their possible synonyms. Group G2 consists of words that are related to *online educational technologies* and their synonyms. In this context, synonym refers to a term that is related to the main keyword. Since we consider any combination of G1 keywords with G2 keywords, we use the OR operator between words from the same group and the AND operator between words from different groups. Hence, the summarized search string was (1 OR 2 OR ... OR 8) AND (9 OR 10 OR ... OR 20). Small variations in the search string were applied to obtain the relevant studies from the databases since they have different search engines.

Then, we defined the digital libraries in which we applied the search string to obtain the primary studies. We considered digital libraries in the area of computation that have satisfactory availability of studies, allow search using keywords and have high bibliographic relevance. We selected the following databases: ACM Digital Library, IEEE Digital Library, Science@Direct, Scopus, EI Compendex, and ISI Web of Science.

Next, we defined the selection criteria (inclusion, exclusion, and quality), which will serve as the basis for the selection process throughout the study. These criteria are based on all previously defined information and aim at improving the results that are obtained via SLR [27]. We consider three types of criteria: inclusion criteria (minimum criteria that articles must satisfy to be included); exclusion criteria (criteria that eliminate a study from selection); and quality criteria (criteria that are used to rank the selected studies according to their quality). The inclusion and exclusion criteria that were defined for this SLR were based on [28], with small changes. The inclusion criteria are that the studies are peer-reviewed and

TABLE I
RESEARCH QUESTIONS OF THE SYSTEMATIC LITERATURE REVIEW

Research Question	**Description and Motivation**
RQ-01: What are the main reasons for using collective intelligence in online educational technologies?	This question seeks to identify the problem that has been addressed in the study, the problems that CI helped solve, and how CI was used in the environment.
RQ-02: What are the benefits of using collective intelligence in online educational technologies?	This question focuses on whether the analysed studies provide evidence of benefits of the use of CI within online educational technologies
RQ-03: What difficulties are encountered in the use of CI in online educational technologies?	This question focuses on whether the analysed studies provide evidence of difficulties that are encountered in the use of CI within online educational technologies.

primary studies that use CI in online educational technologies. A study must meet all inclusion criteria to be selected for the SLR. However, satisfaction of a single exclusion criterion is sufficient to exclude the study from the SLR. The main exclusion criteria of this SLR include non primary, duplicated, incomplete, domain-specific or no peer-reviewed studies, short papers, language other than English, and outside of scope [28].

As the quality criteria, we reused those presented in [28]. The quality criteria that were defined for this SLR consist of a set of 12 questions that evaluate aspects of the analysed studies such as the reasoning, clarity of the objectives, proposed techniques, results presentation, and limitations. They also evaluate the description of the application context, the possibility of expansion to other contexts and the presentation of tools and/or a proposal evaluation. For each question, a grade for the study is assigned. We adapt the possible answers to the same scale for all questions (yes = 1.0, partially = 0.5 and no = 0.0). Hence, an article can have a quality ranging from 0 to 12 points (max quality). The cutoff was set as 6 (50%), inclusive.

Finally, we defined the process of selecting the studies. The process initially consists of executing the search string on the selected databases, extracting the results (file with references BIB) and importing them into the tool *parsif.al*. This tool guides the researcher in conducting all the steps of an SLR more easily. With the inclusion of the obtained studies in the tool, it is necessary to begin the process of study selection based on the predefined criteria via the following steps, according to [27]:

1) Remove duplicate studies;
2) Read the titles, abstracts, and keywords of the studies, and exclude those that satisfy exclusion criteria;
3) Read the introduction and conclusion sections from studies that were approved in step 2, and exclude those that satisfy exclusion criteria;
4) Obtain the full versions of the selected primary studies (usually in PDF format) from the databases;
5) Analyse the quality of the studies according to the quality criteria, and exclude those for which the quality score $< 50\%$;
6) Read the full studies, and extract the necessary data based on the extraction form.

In the case of doubt regarding the inclusion of an article in a step, the article will be approved for the next step. At the end of the process, the remaining studies will be submitted for extraction of the necessary data for general and specific analyses to satisfy the objectives of the SLR. We created an extraction form that contains all the data that should be extracted from the selected studies based on [28]. The complete data extraction form is presented in Table II. The first five data items are general data on the studies, while the last three are data items that are used to answer our RQs.

After defining the SLR protocol, the execution process begins with the execution of the search string on each selected database. For this, we performed an initial study on how each database search engine operates. Unfortunately, the search string needed minor adjustments to perform properly in some databases due to their requirements. Fortunately, all databases allowed the results to be exported to BIB files, which facilitated the process of extracting the results and importing them into SLR tools. Thus, the results were exported to the BIB files and imported into the *Parsif.al* tool. Table III presents the obtained results for each selected database.

According to Table III, the database with the most articles was Scopus (152, 27.9%), which was followed by Science@Direct (133, 24.5%). Next, EI Compendex had 95 studies (17.4%), followed by ISI Web of Science with 82 (15%). Finally, the databases with the fewest articles were ACM Digital Library with 59 studies (10.8%) and IEEE Digital Library with only 24 studies (4.4%). In total, 545 studies were selected and extracted.

All 545 studies were retrieved and uploaded into the *Parsif.al* tool through BibTeX files. Then, we executed the defined process. Fig. 1 presents a summary of the performed process and the results that were obtained in each step.

According to Fig. 1, the initial step was to obtain the studies from databases and to group them together using the *Parsif.al* tool. The tool automatically removed the duplicate studies (a

TABLE II
COMPLETE DATA EXTRACTION FORM

Number	Study information	Description and possible values
1	Study id	Number used to identify the study (index - (template Sxx))
2	Authors, year, title, and country	General information about the study
3	Study type	Journal, workshop, conference, or other
4	Study application context	Industry, academy or both
5	Research method [30]	Controlled experiment, Case study, survey, ethnography, research action, illustrative scenario, or not applicable
6	RQ1 Main objectives	Why and for what is CI used within educational environments?
7	RQ2 Evidence of benefits	Evidence (positive or negative) of benefits of the use of CI with or without empirical evaluation
8	RQ3 Evidence of difficulties	Evidence (positive or negative) of difficulties that are encountered in the process of using CI with or without empirical evaluation

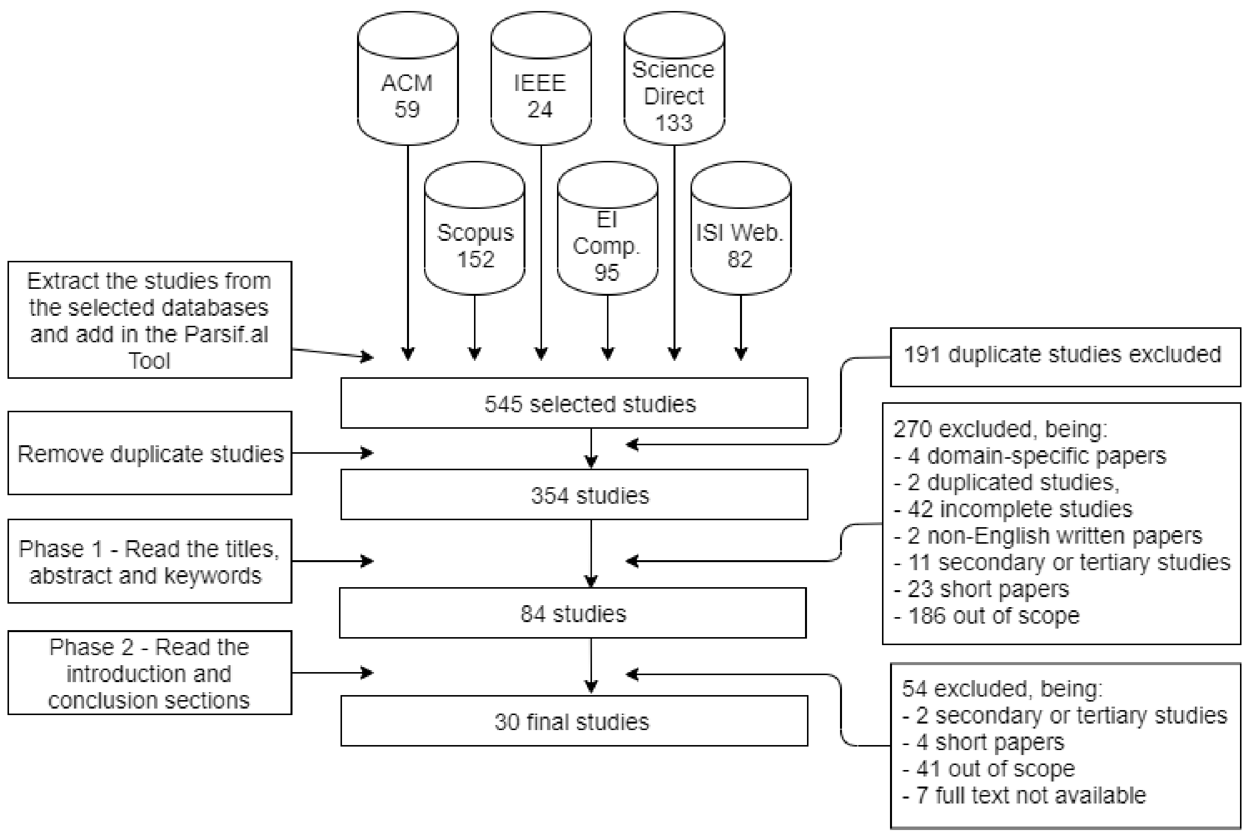

Fig. 1. Summary of the performed process (based on [28]).

total of 191 studies), which left a total of 354 studies to be analysed. Next, we read the titles, abstracts, and keywords of the studies and excluded 270 studies for the following reasons: 4 domain-specific papers, 2 duplicated studies, 42 incomplete studies, 2 non-English papers, 11 secondary or tertiary studies, 23 short papers (<4 pages), and 186 studies that do not use CI in online learning environments (outside of scope). Thus, 84 studies remained.

Next, we read the introduction and conclusion sections of the studies and excluded 54 studies for the following reasons: 2 secondary or tertiary studies, 4 short papers (<4 pages), 41 studies that do not use CI in online learning environments (outside of scope), and 7 studies for which the full text was

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TABLE III
NUMBER OF EXTRACTED STUDIES FOR EACH DATABASE

Id	Database name	Qty	%
1	IEEE digital library	24	4.4%
2	ACM digital library	59	10.8%
3	ISI Web of Science	82	15.0%
4	EI Compendex	95	17.4%
5	Science@Direct	133	24.5%
6	Scopus	152	27.9%
	TOTAL	**545**	**100%**

TABLE IV
SELECTED STUDIES AND THEIR QUALITY ASSESSMENT RESULTS

ID	Author	%	ID	Author	%
S01	[31]	70%	S16	[32]	50%
S02	[33]	55%	S17	[34]	80%
S03	[35]	80%	S18	[36]	60%
S04	[37]	75%	S19	[38]	80%
S05	[39]	65%	S20	[19]	80%
S06	[40]	70%	S21	[41]	80%
S07	[42]	55%	S22	[43]	85%
S08	[44]	65%	S23	[45]	55%
S09	[46]	65%	S24	[47]	85%
S10	[48]	50%	S25	[49]	55%
S11	[50]	60%	S26	[51]	60%
S12	[52]	55%	S27	[53]	85%
S13	[54]	60%	S28	[55]	85%
S14	[56]	90%	S29	[57]	85%
S15	[58]	75%	S30	[59]	60%

not available online. Finally, the studies underwent a quality assessment. The 30 resulting studies are listed in Table IV with their respective evaluations of quality (the numbers are rounded).

With the studies properly selected and classified, we read the full text and extracted the general and specific data for the extraction form (Table II). The data were analysed, and the results are presented in Section III. A discussion of these data is presented in the Section IV.

III. DATA ANALYSIS PRESENTATION

After obtaining the studies, they were completely read and the data of the extraction form, which is presented Table II, was obtained for each study using the *Parsif.al* tool. This tool exports the data in CSV files to facilitate analysis and manipulation. First, we performed a **descriptive analysis of the data**, in which the studies were analysed via a general approach to identify useful information in the data, which provides summaries of the studies samples. The following variables were analysed: quality of each study, year of publication, study source, country of the authors, application context, research method, and educational level.

TABLE V
QUALITY ASSESSMENT RESULTS

Qual. (%)	Quantity	Studies
50	2	S10, S16.
55	5	S02, S07, S12, S23, S25.
60	5	S11, S13, S18, S26, S30.
65	3	S05, S08, S09.
70	2	S01, S06.
75	2	S04, S15.
80	5	S03, S17, S19, S20, S21.
85	5	S22, S24, S27, S28, S29.
90	1	S14.

The first variable that was analysed was the study quality. This metric corresponds to a percentage (0 to 100%) that represents the score that is assigned to the study based on the score for each quality question that is defined in the SLR. A score of 0% indicates a study of minimal quality, and a score of 100% indicates the highest quality study possible. Fig. 2 illustrates the number of studies that were assigned each score.

According to Fig. 2, the quality score varies among the selected studies, with the scores 55, 60, 80, and 85 being the most frequent (5 studies for each). The highest score was 90%, which was obtained by only one study. Overall, the average awarded score was 69.17 and the median 67.5. Additional details about the studies and their quality scores are presented in Table V. The data indicate that 7 studies (S02, S07, S10, S12, S16, S23, and S25) obtained a quality assessment that was considered low (<60%). Ten studies (S01, S05, S06, S08, S09, S11, S13, S18, S26, and S30) obtained an average quality assessment (<75%). Seven studies (S03, S04, S15, S17, S19, S20, and S21) were assessed as being of satisfactory quality (<85%). Finally, only 6 articles (S14, S22, S24, S27, S28, and S29) presented with great quality (≥85%).

The second variable that was analysed was the year of publication. Even without using filters in the search process, the oldest study was published in 2007 (13 years ago). Fig. 3 presents the year of publication of the studies. The number of studies, despite remaining stable until 2012, presents a slight trend of growth over the years, and the most studies were conducted in 2018 (6 or 20%). The data for 2019 were obtained in the middle of 2019, and although a smaller number of studies was expected, the number of studies almost equalled that in 2018 (5 or 16.6%). The years 2015, 2016, and 2017 presented 3 studies each (10% each). The years 2007, 2013, and 2014 presented 2 studies each (6.6% each). Finally, the years 2008, 2010, 2011, and 2012 presented 1 study each (3.3% each).

The third variable that was analysed was the type of source in which the article was published. Fig. 4 presents the studies' sources. According to the figure, most articles came from conferences (approximately 57%), 30% of the studies came from journals, and 10% came from workshops. Only 1 study (3%) was a book chapter.

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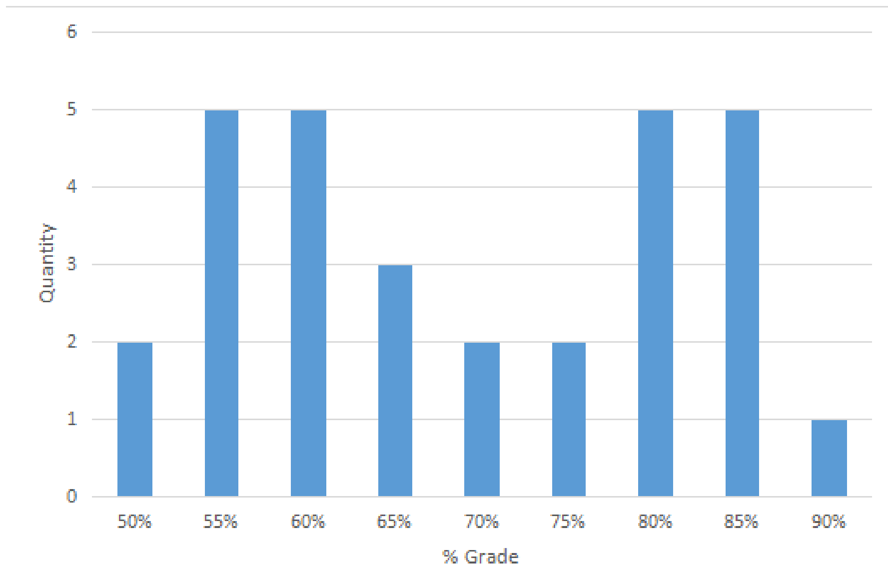

Fig. 2. Quantity of studies by the assigned grade.

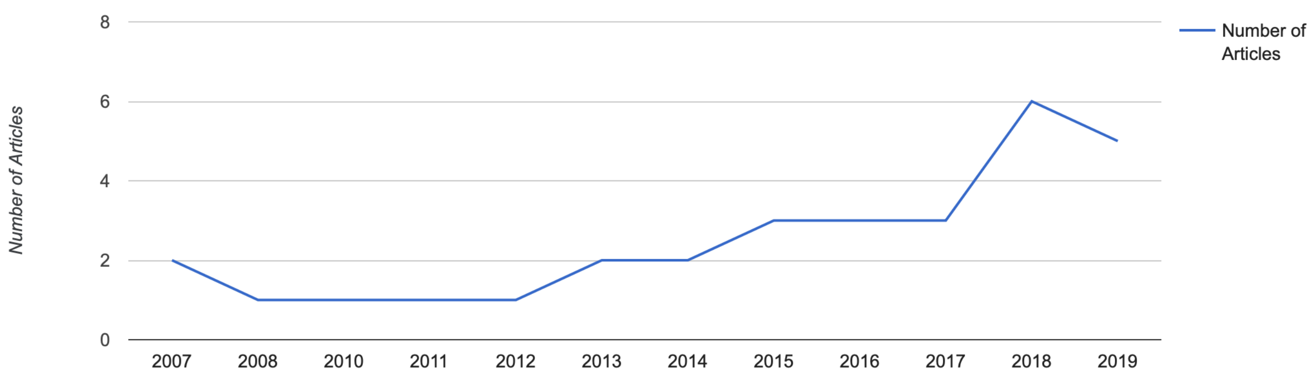

Fig. 3. Publication years of the studies.

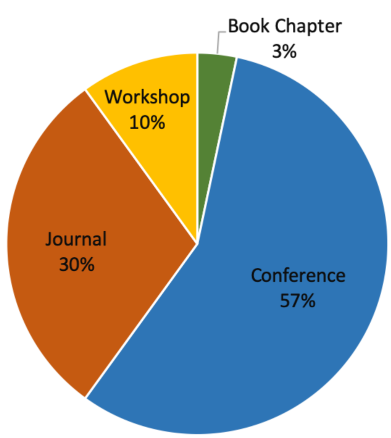

Fig. 4. Sources of the studies.

The fourth variable that was analysed was the country of the authors of the studies, which was always regarded as the country of the first author. Table VI presents the data on the countries. According to the table, most of the studies were published by authors from universities in the USA (7 or 23%), followed by authors from Spain and China (4 or 13% each). Other countries that produced 2 studies were Australia, Taiwan, Netherlands, Canada, and Greece. Finally, the countries that produced only one study were Bosnia and Herzegovina, Japan, Ecuador, France, and Sweden.

The fifth variable that was analysed was the application context (academy, industry or both). The application context is academic if the study was conducted in a school and/or university, usually with the students and teachers of the institution. A study was considered to correspond to industry if it was conducted within the context of companies and/or businesses. The context can be both academy and industry if the study was conducted in both contexts. Fig. 5 illustrates the obtained data in percentage terms. Table VII presents the results in more detail.

Half the studies did not specify the context in which the

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TABLE VI
STUDIES BY COUNTRY

Country Name	Quantity of studies
USA	7
Spain, China	4
Australia, Taiwan, Netherlands, Canada, Greece	2
Bósnia and Herzegovina, Japan, Ecuador, France, Sweden	1

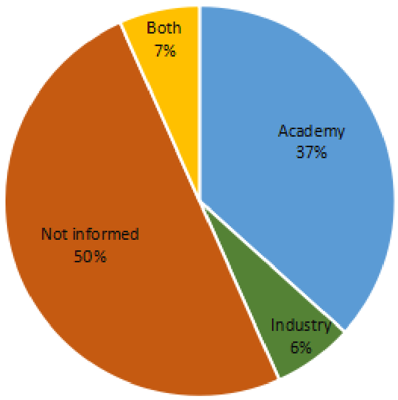

Fig. 5. Application Contexts of the studies.

TABLE VII
APPLICATION CONTEXT RESULTS

Application Context	Quantity	Studies
Not specified	15	S01, S02, S03, S04, S06, S07, S08, S09, S11, S12, S18, S21, S23, S25, S28.
Academic	11	S05, S10, S13, S15, S16, S20, S22, S24, S26, S29, S30.
Industry	2	S19, S27.
Both	2	S14, S17.

work was conducted (15 or 50%) (S01, S02, S03, S04, S06, S07, S08, S09, S11, S12, S18, S21, S23, S25, and S28). It is worth mentioning that the context must be explicitly presented in the study to be included in the count. Of those that did specify the context, 11 (37%) of them (S05, S10, S13, S15, S16, S20, S22, S24, S26, S29, and S30) were conducted in the academic context while 6% (S19 and S27) were conducted in the industrial context. Finally, 2 (7%) (S14 and S17) were conducted in both contexts.

The sixth analysed variable was the research method, according to [30]. A research method refers to a scientific procedure that was used by the authors to design or conduct the study or to obtain or analyse the empirical results [30]. Many research methods can be applied, such as controlled experiments, case studies, and surveys. It is also possible to combine various methods into a mixed research method. Fig. 6 illustrates the obtained data in percentage terms. Table VIII presents the results in more detail.

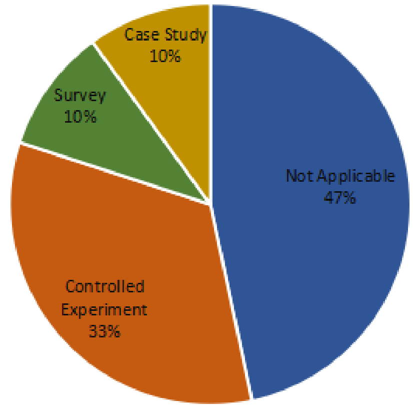

Fig. 6. Research methods of the studies.

TABLE VIII
RESEARCH METHODS RESULTS

Research Method	Quantity	Studies
Not Applicable	14	S02, S05, S10, S11, S15, S16, S17, S18, S19, S21, S25, S27, S28, S29.
Controlled Experiment	10	S03, S04, S09, S12, S13, S14, S20, S22, S24, S26.
Study Case	3	S06, S07, S08.
Survey	3	S01, S23, S30.

Fourteen (47%) (S02, S05, S10, S11, S15, S16, S17, S18, S19, S21, S25, S27, S28, and S29) of the studies did not apply or did not report any research method. Ten (33%) (S03, S04, S09, S12, S13, S14, S20, S22, S24, and S26) conducted controlled experiments as a research evaluation technique. Finally, 3 studies (10%) (S06, S07, and S08) conducted case studies, and the remaining 3 (10%) (S01, S23, and S30) used survey as a research method

The seventh variable that was analysed was the educational level. This could be a basic, primary, secondary, high school or university level. Unfortunately, the vast majority of studies did not specify clearly the educational level. Fig. 7 illustrates the obtained data in percentage terms. Table IX presents the results in more detail.

Among the studies, 22 (or 71%) (S10, S12, S16, S17, S21, S29, S30, S28, S23, S25, S27, S11, S15, S18, S09, S08, S07, S06, S04, S03, S02, and S01) did not specify the educational level. Of those that specified the level, 8 or 100% were conducted at the university level (S13, S14, S20, S24, S26, S22, S19, S05). Only 1 study (3%) (S05) was conducted at the high school level, in addition to the university level.

Next, we performed a **more elaborate analysis to answer the RQs** that are listed in Table I. **RQ1 aims to identify the problem that has been addressed in the study**, the problems CI helped solve and how it was used in online educational technologies. As we read the articles, we realized that CI was used to solve several educational problems; thus,

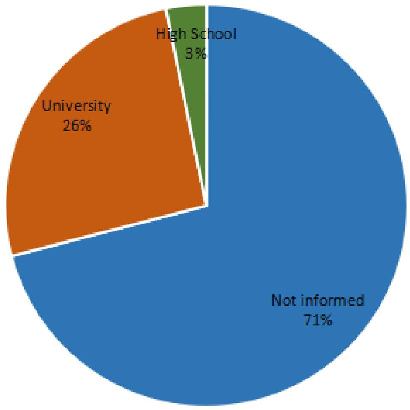

Fig. 7. Educational levels of the studies.

TABLE IX
EDUCATIONAL LEVEL RESULTS

Educational Level	Quantity	Studies
Not Specified	22	S10, S12, S16, S17, S21, S29, S30, S28, S23, S25, S27, S11, S15, S18, S09, S08, S07, S06, S04, S03, S02, S01.
University	8	S13, S14, S20, S24, S26, S22, S19, S05.
High School	1	S05

CI can be used to solve problems in several ways. We grouped the involved issues according to the objective of using CI in online educational technologies. Fortunately, we found that CI is used in online educational technologies for three main purposes: to improve collaborations and collaborative learning (G1); to create educational content (G2); and to improve the educational process (G3).

Group G1 corresponds to collaborative learning. This group includes studies that used the power of CI to improve collaborations and collaborative learning. Study S17 aimed at enhanced collaboration on online education through connecting collaborative and crowd work [34]. S20 used CI to enhance collaboration through a process of managing and presenting ideas and run-time assessment within the classroom. This, ensured greater interaction between students during the learning process and, consequently, yielded better results via collaboration between them [19]. Study S13 proposed a system called SHAREK, which was a learning resource repository, to which content could be added not only by the course teachers but also by the students, which included original content and content from other sources [54]. The approach that was proposed by S13 enables the construction of global knowledge via the use of CI based on the individual knowledge of each student, which was obtained in various ways, and the platform enabled this knowledge to be shared among all students.

Study S29 proposed a framework that is based on knowledge building and collective wisdom, aiming to facilitate the resolution of complex learning problems through individual interaction between students to enable collaborative learning and the construction of social knowledge [57]. Also working with this social dimension of learning, study S23 sought to use peer power to facilitate individual learning rhythms and transform the learning community into an autonomous and decentralized form [45]. Study S23 can also be classified into group G3.

Finally, the remaining studies in this group address quality issues. Study S18 proposes a process with quality control techniques and integrates crowd confidence with collaborative learning, which involves several steps, such as content creation, knowledge assessment, and grading [36]. Study S18 can also be classified into groups G2 and G3. Study S15 improved confidence in collaborative environment scenarios by using CI in environmental activities [58].

Group G2 corresponds to content creation. This group includes the studies that used the CI to create educational content. Study S22 used the concept of CI for the creation of microcourses (short video lessons) by the students. The proposed model utilizes crowdsourcing and collaborative learning by proposing a more student-centred approach for creating collaborative content [43]. Study S22 can also be classified into groups G1 and G3. With a similar proposal, study S10 used CI to create interactive video lectures through users' own interactions with the system [48].

Study S14 presented the VidWiki platform, in which students create, improve the quality, and presentation of educational videos by inserting subtitles, correcting mistakes or even translating texts [56]. With the same objective of creating e-learning content, study S26 defined the CrowdLearn concept, which exploits the wisdom and creativity of the crowd to make content more structured [51]. Aiming at creating short lectures (on average 5 minutes), study S30 implemented an open and multilingual repository and allowed volunteers around the world to collaboratively create and add short lectures to which other users could also make contributions, thereby further enhancing the contents of the repository [59]. Study S28 used CI to create content by using the SCORM to create comments [55].

Also from the perspective of content creation, study S05 used crowdsourcing to create a dictionary with the application of CI to add valuable knowledge [39]. Study S09 used crowdsourcing to construct labels for a predefined data set [46]. A very interesting study, namely, study S04, presented ConceptScape, which is a platform capable of generating concept maps for available videos (usually lectures). The most interesting aspect of the proposed approach is the use of CI to enable the creation of concept maps collaboratively among the users [37].

A subgroup with a large quantity of articles with similar objectives are studies that involve translation problems. Study S24 used many professional translators to translate an MOOC from Greek to English [47]. Study S27 also used many translators, but these were not professional translators; nevertheless, they managed to produce high-quality translations [53]. Study S19 used CI to initially translate course materials into the Chinese language. Study S19 used CI to adapt student skills to course materials, to formulate an initial mapping

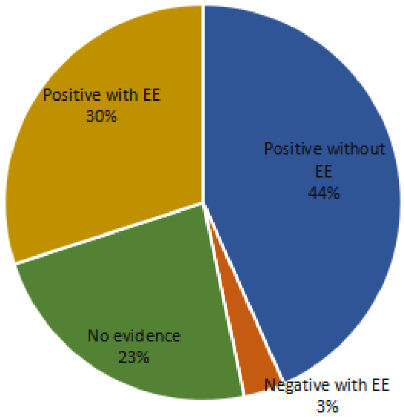

Fig. 8. Classification of the benefits of the studies.

questionnaire for students, and to assess student knowledge throughout the course [38]. Finally, study S03 developed a set of multilingual educational content (from texts, forums, and subtitles) through the use of large-scale CI [35].

Group G3 corresponds to improvements in the educational process. This group includes the studies that used CI to improve the educational process, including benefits to the actors. Study S06 selected teaching assistants to facilitate the teacher's work using crowdsourcing from among the most prominent students in the course [40]. Also in the context of facilitating the teacher's work but in the student evaluation process, study S08 created a model that uses human computation to assign grades to students without the need for prior knowledge of the answers and using only individual knowledge that is extracted from the students [44].

CI was also used in study S21 for automatic recognition of student engagement throughout the teaching process [41]. Using a more complex approach, study S16 proposed a methodology for authoring ITS using human computation, which aimed at increasing learning and intrinsic motivation [32]. Study S02 presents the PerspectivesX tool, which uses CI to group student responses to improve collaborative learning in the system [33]. Finally, study S01 creates a collective knowledgebase using CI in all educational actions [31].

Next, **RQ2 seeks to identify the benefits** of using CI in online educational technologies. This question focuses on whether the analysed studies present evidence of benefits of the use of CI within online educational technologies. To address this question, we considered the benefits of using CI in online educational environments that are identified by the authors. The benefits were classified as positive (improves an aspect) or negative (negatively affects an aspect) and as *with EE* (with empirical evaluation if any research method in item 5 of the extraction form was used) or *without EE* (without empirical evaluation if there was no use of any research method and the results represent only the opinion or findings of the author). If no evidence of benefit was presented in a study, the study was classified as *No Evidence*. Fig. 8 presents the classification of benefits of the studies based on these criteria in percentage terms, and Table X presents the results in more detail.

According to Fig. 8 and Table X, 22 (74%) of the studies presented positive evidence of benefits, of which 13 were classified as positive without EE (44%) (S02, S03, S05, S08, S09, S10, S16, S17, S18, S23, S25, S27, and S28) and 9 as positive with EE (30%) (S01, S04, S13, S14, S20, S22, S24, S26, and S30). Seven studies (23%) (S06, S07, S11, S15, S19, S21, and S29) did not present evidence of benefits. Only one article (3%) (S12) demonstrated negative benefits via empirical evaluation.

The positive benefits with EE include the following: The use of CI encouraged students to share resources and use the system regularly [54]. The use of CI encouraged students to create video annotations due to the potential to benefit their peers and because CI reduced the time that was required to create these videos [56]. Study S20 indicated that CI improves student participation and group behaviours, along with performance and knowledge acquisition, by stimulating collaborative learning [19].

CI transforms student participation by making it more active and improves learning quality [51]. The use of CI enabled scalable content creation and motivated students to participate [59]. The results that were obtained using CI were equivalent to expert results in the translation results of study S24 [47], and the results in creating concept maps were similar to those of experts [37]. According to study S22, CI stimulates creativity, teamwork, communication, and collaboration among students [43], and study S01 indicated that CI brings participants satisfaction [31].

The positive benefits without EE include the following: The use of CI can improve learning outcomes [36], [48], [55], increase the learning scale [33], [49], and provide scale knowledge and training [34]. Studies have shown that CI facilitates daily tasks in the system, such as content management and evaluations [55], solves the problem of hiring experts [32], and decreases the total system cost [46], [53]. In addition, the results obtained using CI are equivalent to those of specialists [44]. The only **negative benefit with EE** is identified in study S12: the results that are obtained using CI depend on the application context, and negative results are obtained in various cases. **No negative benefits without EE** were identified by the studies.

Finally, **RQ3 sought to identify the difficulties** that were encountered in the process of using CI in online educational technologies. This question focuses on whether the analysed studies present evidence of difficulties that are encountered in the use of CI within online educational technologies. To analyse this question, we consider the difficulties that were identified by the authors in using CI in online educational environments. Similar to the benefits, the difficulties were classified as positive (difficulty in using CI) or negative (no difficulty) and as *with EE* or *without EE*. If no evidence of difficulties was presented in a study, the study was classified as *No Evidence*. Fig. 9 presents the classification of difficulties of the studies based on these criteria in percentage terms, and Table XI presents the results in more detail.

According to Fig. 9 and Table XI, 12 (40%) of the studies presented positive evidence of difficulties, among which 10 were classified as positive without EE (33%) (S03, S16, S18,

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TLT.2021.3073559, IEEE Transactions on Learning Technologies

TABLE X
BENEFIT RESULTS

Benefit Evidence	Quantity	Studies
Positive with EE	9	S01, S04, S13, S14, S20, S22, S24, S26, S30.
Positive without EE	13	S02, S03, S05, S08, S09, S10, S16, S17, S18, S23, S25, S27, S28.
Negative with EE	1	S12
Negative without EE	0	-
No evidence	7	S06, S07, S11, S15, S19, S21, S29.

TABLE XI
DIFFICULTY RESULTS

Difficulty Evidence	Quantity	Studies
Positive with EE	2	S12, S24
Positive without EE	10	S03, S16, S18, S20, S23, S25, S26, S27, S28, S30.
Negative with EE	0	-
Negative without EE	0	-
No evidence	18	S01, S02, S04, S05, S06, S07, S08, S09, S10, S11, S13, S14 S15, S17, S19, S21, S22, S29.

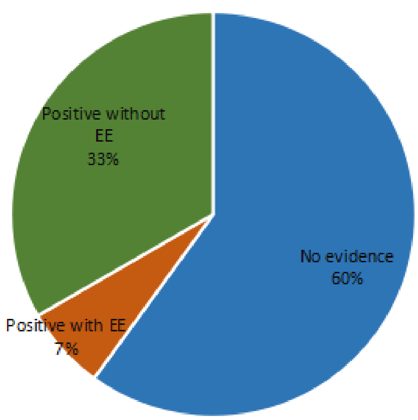

Fig. 9. Classification of difficulties of the studies.

S20, S23, S25, S26, S27, S28, and S30) and 2 as positive with EE (7%) (S12 and S24). More than half of the studies, namely, 18 studies (60%) (S01, S02, S04, S05, S06, S07, S08, S09, S10, S11, S13, S14, S15, S17, S19, S21, S22, and S29), did not present evidence of difficulties. No article presented negative evidence of difficulties.

The positive difficulties with EE include the following: Study S12 indicated that the student's motivational factor may contribute to unsatisfactory results since some members are only concerned with getting benefits and not behaving properly [52]. Study S24 indicated that the task that is sent to the crowd must be clearly defined and well contextualized since a lack of clear information can make the task more challenging for the crowd, thereby harming the results [47].

The positive difficulties without EE include the following: Study S16 indicated that there should be greater concern when designing educational tasks using CI since they should be effective in the short term and motivational in the long term [32]. According to study S20, a prior skill set is necessary for the student to conduct the knowledge building process using CI effectively [19]. Similarly, study S30 showed that there should be greater management of students from the crowd to that they can successfully complete tasks and produce satisfactory results [59]. Study S27 indicates that there should be quality control to ensure expert-like results [53]. Study S18 showed that a quality model is required for obtaining reliable results [36]. Study S26 identified privacy and security concerns throughout the process [51]. Study S28 identified syncing issues when a crowd attempts to simultaneously access resources and a lack of collective resource manipulation patterns, thereby limiting the application power of CI [55]. Study S25 indicated that techniques must be used to attract a crowd [49]. Finally, study S03 showed that the platforms for using CI are limited [35].

IV. DISCUSSION

This section presents and discusses the main conclusions from the results that were presented in Section III. One of the steps of the SRL is to evaluate the quality of the selected studies by analysing various important aspects. Most of the presented studies were of low-to-medium quality (score <75%). Thus, **the published studies in the area are failing in the presentation of various aspects** such as clarity of reasoning, objectives, context, and proposed techniques, and/or in the presentation of their methodology, the results, and limitations. This harms researchers that work with CI in online educational technologies since it makes the studies difficult to understand and hinders possible comparisons of the results and future replications in other contexts.

Even though CI is not a new concept, the first studies on CI and online educational technologies were published in 2007. However, **there has been a moderate trend of**

growth in the use of CI in online educational technologies since 2012. This growth is related to the emergence of new online educational technologies at that time, such as Udemy (2010), Udacity (2011), edX (2012), and Coursera (2012). These technologies have substantially increased the number of students in online environments and have enabled cooperation among them. However, **most studies are conducted in the academic context**. As the studies in this area are more recent, the first validations and results come from the academy and are transferred to the industrial context. The interest of researchers and the sources of publication (2x more studies are published in conferences) indicate that **the combination of CI with online educational technologies is an emerging area**. However, almost **half of the studies did not use research validation methods**, which is a negative aspect for the community since that evidence is critical for ensuring that the developed approaches perform properly. In addition, **most studies used CI at the university educational level**. It is easier to work with students at this educational level, but this leaves us with an open question: *How would the application of CI perform at other educational levels?*

Regarding the SRL RQs, our first RQ was **RQ1: What are the main reasons for using CI in online educational technologies?** Throughout the results, we visualized many applications of CI in online educational technologies. We grouped the presentations according to the issues that were encountered in using CI. However, to answer our first RQ, we must further investigate the potential for the use of CI within online educational technologies. Thus, the application potential and the main reasons for using CI are as follows:

- **CI can be used to enhance the collaboration among individuals with online learning technologies [34]:** The design and development of these technologies typically focus on individual student interaction. The lack of suitable interactions between students in these environments stimulates individual learning, thereby affecting the creation of a motivated learning community [45]. It is possible to use CI to promote more collaborative interactions among students to yield learning benefits [19].
- **CI promotes interaction among students [57] and facilitates the solution of complex educational problems:** Many applications are available that solve complex computational problems using thousands of users, such as reCAPTCHA [11], Wikipedia [10], and Duolingo [12]. Hence, it is possible to use CI to solve complex educational problems such as the creation of tags for educational resources (problems, music, and videos), which is known as collaborative tagging, to improve the results of the resource recommendation algorithms in these systems [60]; the translation of the educational resources into other languages [56]; and the automatic recognition of student engagement [41] to prevent student dropout from using the technology.
- **CI can be used in the process of educational resource creation by students [36]:** All the educational resources that are available in online educational technologies are created and provided by the teacher or tutor of the environment, which can generate an overload of work and fail to fully utilize the students' potential in the process. Given the importance of social learning, the great value of these environments is related not only to the content that is inserted by the professor and presented to the students but also to how these students form an effective learning community and, especially, how the contents are created and used creatively and intuitively to solve problems [55]. It is possible for students to use CI to create educational resources, for example, to create texts [35], forums [35], short video lessons [43], interactive video lectures [48], short lectures [59], subtitles for videos [35], [56], comments [55], dictionaries [39], labels [46], and concept maps [37].
- **CI can be used in the process of maintaining educational resource repositories in online learning technologies:** In all online educational technologies, we have a repository of educational resources that are made available to students. This repository is usually maintained by the teacher or tutor. The use of CI enables students contribute to this process by adding new educational resources [54], removing or updating resources, and organizing resources hierarchically [51], [59] or mapping them to the related domain or subject. The students can also contribute assessments of the educational resources [36], [53], [56], [59], which can be used by educational technologies to provide better resource recommendations.
- **CI allows for the decentralization of the learning process [45], thereby enabling students to learn from their peer interactions and evaluate themselves:** The use of CI in the learning process through the creation of virtual communities enables students to learn collectively, cooperatively, and permanently, which modifies the students' relationship with knowledge [4]. The pedagogical basis should focus on the process of creating and sharing knowledge among peers. In this way, CI has the potential to improve Peer Learning and CrowdLearn [51]. Moreover, CI enables the decentralization of the evaluation process of the students, thereby enabling evaluations to be conducted among peers, which is known as Peer Assessment [53]. CI in learning processes affects both teachers and students [4].
- **CI can facilitate the application of new teaching methodologies based on the students' active role:** In most of the online educational technologies, the teaching models are focused on individualizing learning [4], with the teacher having a central role in teaching. The use of CI enables a new type of learning that is more student-oriented, in which students are the primary focus of the teaching and learning process [54]. Via this approach, the students can play new active roles in the learning process, e.g., as teaching assistants [40].

Our second RQ was **RQ2: What are the benefits of using CI in online educational technologies?** In analysing the results in an attempt to answer our second RQ, we observe that 74% of the studies presented positive evidence of benefits.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TLT.2021.3073559, IEEE Transactions on Learning Technologies

The presented evidence of benefits is limited to the application scope and context of the corresponding studies, and there is no guarantee that such benefits can be generalized to any CI application. However, the results demonstrate that CI has the potential to provide great benefits to students and teachers. The main benefits include the following:

- **CI improves the student participation in online educational environments [19], [54], [56], [59]:** The use of CI can encourage students to participate in activities in an educational environment by serving as a motivational factor for the creation and sharing of resources. CI facilitates the maintenance of regular student participation [54] and prevents student dropout.
- **CI helps decrease the total cost of execution of an online educational technology [46], [53]:** The management of educational resources of a technology is costly due to the need for specialists to perform this activity. The studies have indicated that it is possible to manage educational resources using CI, which reduces the time for creating educational resources [56], enables the scalable creation of resources [59], and maintains equivalent quality of the contents that are created by the students and specialists [37], [44], [47]. This decreases the workload for the specialist.
- **CI improves the performance of and knowledge acquisition by students [51]:** Studies have shown that CI improves student learning [36], [48], [55], which is due mainly to more active student participation in the process. In addition, individual student skills such as creativity, teamwork, communication, and collaboration are stimulated when using CI techniques within an online educational environment [43].

Finally, our third RQ was **RQ3: What difficulties are encountered in the use of CI in online educational technologies?** Analysing the results in an attempt to answer our third RQ, we observe that (40%) of the studies presented positive evidence of difficulties. Similar to the benefits, the difficulties that are presented here are limited to the scopes of the respective studies; however, these difficulties must be considered in the application of CI within online educational technologies. When not properly managed, these difficulties can compromise the results. Thus, when applying CI, the following difficulties should be considered:

- **Concern regarding the motivational factor that is used in the CI process [49], [52]:** The use of CI imposes more responsibilities on students within the educational environment. These additional responsibilities may decrease the students' motivation and result in non-participation in the required activities, which would yield unsatisfactory results of the CI application. A motivational factor in the environment is necessary for keeping students motivated to participate in the process. However, it is necessary to carefully measure the application of this factor so that students are not concerned only with the benefits and forget about learning.
- **Concern regarding the design of educational tasks [32]:** The educational tasks that are presented in the online learning technologies should reflect the collective aspect and strengthen the collaboration between students. The use of group tasks is recommended, and individual tasks should be avoided. The tasks must be effective in the short term and motivating in the long run. In addition, the creator of the educational tasks must consider their clarity [47], and each task must be well defined and contextualized. Thus, the training of specialists in the application of CI in this context is recommended [4].
- **The necessity of managing the student crowd [59]:** The use of CI requires better management of the involved processes and people. When using CI in online educational technologies, the person who conducts this management is the teacher. It is necessary to monitor the process of implementing CI more closely and to monitor the progress of activities in the system. Intervention becomes necessary when students are not fulfilling their responsibilities. Without this monitoring, the results become unsatisfactory. Unfortunately, there is a lack of suitable platforms that support the CI process [35]. In addition, quality control is required throughout the process [36], [53].

CI is a very broad and multidisciplinary concept. In this study, we seek to limit the scope of its implementation from the perspective of the integration of computational technologies with the main established educational technologies. To delimit the keywords and their synonyms in our search string, we searched for references in the literature to ensure that all studies that are related to CI in online learning technologies are returned. For this reason, we seek to expand the number of search sources for the studies to attempt to cover the main computational databases that support automatic search. Despite our efforts, some studies that are related to CI and online educational technology may not have been included in this review.

Once the SLR involves subjective decisions in the study selection and data extraction steps, the execution process is prone to mistakes. To minimize the mistakes due to subjective decisions, the process was conducted interactively and always collaboratively by the reviewers, and any conflict was discussed and resolved by all authors. Various studies were selected to evaluate the results that were obtained using the search string and in the selection process. The SLR was carefully designed and evaluated by all authors prior to the execution process. In this SLR, we analyse only studies that were published in English, which generates a bias regarding the publication language.

V. Conclusion

In this paper, we conducted an SLR to investigate and determine how CI has been used within online educational technologies to provide an overview of the use of CI in online educational technologies. The objectives were to answer 3 RQs, which addressed the main objectives of using CI in online learning technologies, the benefits of its use, and the difficulties that were encountered. We presented the entire development of the SLR protocol and the execution process.

We analyse the state-of-the-art applications of CI in online educational environments. Throughout the process of this SLR, 545 studies were identified, of which only 30 were selected for analysis according to the defined selection criteria.

After analysing these studies, we conclude that the quantity of studies exhibits a slight trend of growth over the years. Most studies come from conferences (57%) and journals (30%). The main countries of the authors are USA, Spain, and China. The main context of the application of the studies is the Academy, which corresponds to approximately 37% of the studies. Most of the studies do not present formal research methods (47%), but of those that do, the main research method used is controlled experiment (33%). The main educational level is higher education (university), which corresponds to 26% of the studies. Regarding the RQs, we conclude that there are many applications of CI in online educational environments. However, we have found that the main objectives are to explore the potential for collaboration and collaborative learning in collaborative environments; to create diverse content using the power of many users, especially in content translation; and to improve various educational aspects using group intelligence, such as student learning and assessment processes. Moreover, approximately (74%) of studies presented some positive evidence of benefits, however, approximately (40%) of the studies presented positive evidence of difficulties.

The presented results demonstrate that CI has substantial potential for use in conjunction with online educational technologies to enhance collaboration, interaction, and the learning processes, thereby affecting not only students but also teachers. There are several benefits of using CI in educational environments. However, the combination of CI with educational technologies is an emerging area, and, therefore, further research is needed to understand its full potential. The application of CI in educations environments must be planned from conception since it is a new paradigm of thought and not just a technological change. The obtained results from this SLR are highly important for the online education community since they provide an overview of the primary studies that have been published in the literature on the use of CI with online learning technologies. In the future, we intend to extend this SLR to new contexts and more specific RQs.

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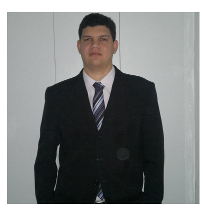

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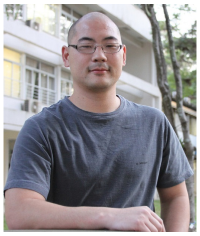

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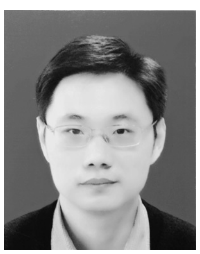

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