Flipped Classroom in Higher Education: A Bibliometric Analysis and Proposal of a Framework for its Implementation

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Abstract—The flipped classroom as an educational model is perfectly aligned with the current demands of higher education. Therefore, the objectives of this article were to carry out a bibliometric analysis of the scientific production of the flipped classroom in higher education (2012-2020) and to propose a framework for its implementation in face-to-face, blended or online learning modalities. The records were recovered from the Web of Science Core Collection and Scopus, from which, after a five-phase methodological process, a consolidated dataset of 782 documents was obtained. The results showed the importance of the subject matter as scientific production reflected a continuous growth during the period of study. For their part, the most productive authors come from various institutions worldwide with an H index of over 50. The collaboration indicators show the growth trend of these indexes over the years, which reflects the capacity to generate national and international impact in the documents published in collaboration. The keywords co-occurrence analysis showed that the flipped classroom as a technological and innovative approach is complemented by active learning, blended learning, e-learning, ICT, teaching method, among others. Finally, a framework with five components was proposed as a basic guide for the implementation of the flipped classroom in higher education.

Keywords—Flipped classroom; Bibliometrics; Higher education; Active learning; Framework; Scientific collaboration; Co-occurrence; Scientific production; Information and communication technology

1   Introduction

Active learning has its axis in pedagogy centered on the activity of the student and his or her involvement in the process of teaching and learning [1]. There are several methods that enable active learning such as concept mapping, brainstorming, collaborative writing, case-based instruction, cooperative learning, role-playing, simulation, project-based learning and peer teaching [2]. Active learning pedagogies have continued to evolve, and new methods have been developed with innovative ways of restructuring learning sessions, such as flipped classroom and gamification ([3]–[5].

In 2007, in Colorado, USA, Jonathan Bergmann and Aaron Sams, chemistry teachers, systematically shaped the use of the flipped classroom (FC) and are considered the founders of this pedagogical model. Since then the FC has spread to a wide community of educational institutions and educators around the world, reaching out to higher education [6]. The FC as a pedagogical model requires the commitment and active participation of students in learning activities both before and in the classroom, all with the contribution of information and communication technologies [7]–[9].

The FC offers students the opportunity to self-regulate their learning, for example, to explore materials such as videos, readings or exercises at their own pace [7]. Pre-class activities allow students to use their learning time independently to acquire fundamental knowledge and skills. While during classes (face-to-face or synchronous), students participate individually and collaboratively, receiving individualized support from the professor [10]–[12]. Classroom activities are student-centred, emphasizing active learning, where the teacher helps the student and not just provides information; this makes them self-directed learners [4], [13], [14]. Therefore, some of the benefits of the application of the FC are improved attention, verification of learning, allows for self-assessment and empowerment of the student in the assessment processes that adapts to their individual interests with flexibility to make decisions about the what, the how and the when, and they learn by assuming commitment and responsibility [15], [16].

The development of information and communication technologies (ICT) and the current situation made the implementation of virtual education the standard at all levels of education. For this reason, higher education institutions have implemented institutional strategies, where professors have carried out trials that serve to achieve learning, a trend that shows that the characteristics of teaching will not be the same in the future [17]. In this context, the covid-19 has accelerated the demand for digital transformation in higher education institutions and professors have been challenged to achieve adaptability and flexibility in the content and design of courses for learning in different training areas. With this, the disruption of traditional teaching becomes evident with online learning models, where the FC has found the most favourable ground to be used and developed with new particularities and demands [12], [16], [18], [19].

There are various methodologies applied in the FC, so their application depends on the mentality, ability, culture, or preference of professors and students. There is no ideal route that guarantees good results [13]. However, once the pedagogical proposal is defined, teaching-learning strategies will be designed with the use of ICT and didactics to achieve the competences foreseen in the pedagogical design. Authors such

as Kim et al. [20], Lo & Hwang [21], DePietro et al. [12] and Hew et al. [18] used the framework as a tool that provides a cohesive structure with validated components. It is adaptable because it allows for different learning styles and areas to be worked with according to the needs of professors and students.

Knowing the trends and regularities of scientific disciplines is therefore necessary and important, and where bibliometrics as an instrumental discipline with a long tradition in the evaluation of science allows the analysis of the behaviour of scientific production in different scientific aggregates by means of bibliometric methods and indicators, with a mathematical-statistical basis [22], [23]. The use of these bibliometric methods and indicators to study the behaviour of disciplines and areas of knowledge is of vital importance given their contributions to the knowledge of the regularities and trends present in the scientific production generated by scientific communities [24]. Obtaining indicators that enable analysis from different perspectives and dimensions (productivity, visibility and impact, networks), as well as helping to understand the aforementioned behaviours and trends, provides key information for the management of scientific activity by specialised communities and the generation of new knowledge [25]. Technological development and computerized methods have facilitated the obtaining of indicators and the visualization of information that help to improve the analysis of results and the regularities present in the results [26]. These provide a powerful approach to analysing a wide variety of bibliometric networks, ranging from networks of dating relationships to networks of co-authorship or co-occurrence relationships [27], [28].

There are previous bibliometric studies related to FC in general [29]–[32]. Their works were oriented to analyzing the growth of scientific production on FC, productivity according to countries, thematic categories, journals, frequency of keywords, impact through citations and bibliometric networks of the analyzed documents. In the field of higher education only studies of reviews, systematic review and meta-analysis of FC were found, some of them are [33]–[35]. These authors highlighted the importance of the use of FC in higher education, demonstrated the improvement in academic performance and student satisfaction with the FC model, and described the main findings or conclusions of the papers analysed in the context of higher education.

In this scenario, the contribution of this article is based on the achievement of two objectives: (1) To identify the behavior of the FC's scientific production in higher education based on indicators of production, collaboration and bibliometric networks, and (2) To propose a framework for implementing the FC in higher education in the modalities of face-to-face, blended or online learning. The first objective is based on bibliometrics as a suitable tool for analysis. For the second objective, some results of the bibliometric analysis have been used in conjunction with the review of the literature [36] to propose a framework for the proper implementation and use of the FC with five basic components: (a) planning, (b) induction session, (c) pre-class activities, (d) in-class activities, and (e) post-class activities.

2 Methodology

2.1 Design and information source

The work is a descriptive study with bibliometric methodology that examines the behaviour of scientific production on FC in higher education. For the search and retrieval of the information, the most recognized multidisciplinary database platforms worldwide were used, Web of Science (WoS) Core Collection and Scopus in the period 2012 to October 2020. For the retrieval of records and the creation of the working dataset, the search equation ("flipped classroom*" OR "inverted classroom*") AND (universit* OR college* OR varsit* OR "higher education" OR "undergraduate education") was used in the fields title, abstract or keywords. Only article or review depending on the quality of these documentary typologies and their contribution to visibility and impact. 2012 was taken as the starting year, because the records retrieved from both databases were recorded from that year onwards.

The 713 and 848 registers recovered from Web of Science and Scopus respectively (Fig. 1) were exported to EndNote, a bibliographic management system with bibliometric features, which made it possible to eliminate duplicates and subsequently create a single database with 1095 documents. Documents whose profiles did not meet the objectives of the study, such as studies that do not refer to higher education as a context or that do not refer to the FC as a learning methodology, were then excluded. After a clean-up process, 782 consolidated documents were obtained (Fig. 1.)
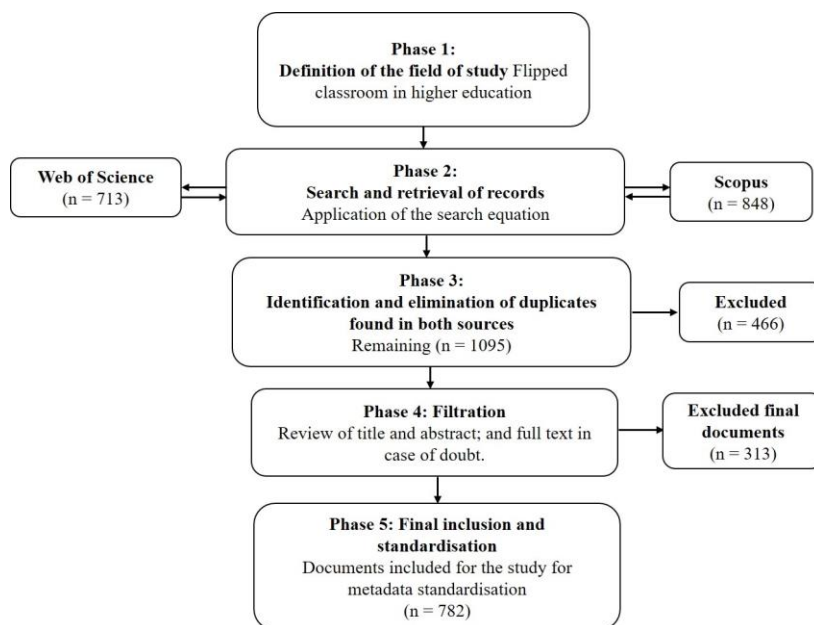

Fig. 1. Methodological process of search, retrieval, selection, standardisation and inclusion of documents for the study

2.2   Analysis and measurement units

The units of analysis considered were articles, authors, documents and keywords. The units of measurement were the indicators of productivity, collaboration and the co-occurrence of keywords with bibliometric networks.

2.3   Data analysis

For the analysis of the information, the programs Excel 2019, Publish or Perish 7, EndNote X9 and VOSviewer v1.6.15 were used. After obtaining the 782 consolidated documents, the collaboration indicators were obtained with Publish or Perish and Excel. With Excel the data was prepared and a process of standardisation of author names and keywords was carried out by constructing thesauri in txt files. The VOSviewer program was used to map the distance-based bibliometric networks according to keywords co-occurrence. To obtain the visualization map, VOSviewer applies the association force normalization technique [37], then the VOS mapping technique "visualization of similarities" [38], and finally the clustering technique [39]. A cluster in the network is represented by a colour and is formed by a set of nodes or items closely related to each other, according to the co-occurrence of keywords, where each node is assigned exclusively to a cluster.

3   Results

Research on scientific production in a specific field is relevant to understand the behaviour of literature in order to suggest future lines of research to related and interested communities. The following results offer a descriptive view with bibliometric methodology. This chapter ends with the proposal of a framework for applying the FC in higher education.

3.1   Scientific production (2012 – October 2020)

In the two documentary typologies analysed: articles and reviews, the number of documents published reveals a sustained and continuous growth from 2012 to 2019, the latter being the highest value (186 documents) (Fig. 2). Likewise, it can be seen that in 2020 there is a trend of growth in the number of publications (148 documents) as the date of data extraction was October 2020. This may be due to the effect of the covid-19 pandemic which generated an increase in the number of investigations. In terms of reviews, the highest number of publications also occurred in 2019 (10 documents) and, in general, they had a constant flow of publications even though the number is lower in relation to research articles. Review articles provide comprehensive information on the topic, answer some questions, and suggest new aspects or trends of FC research.
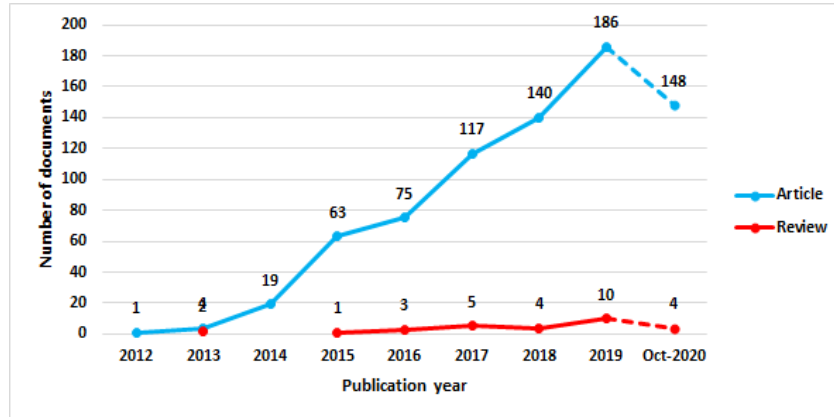
Fig. 2. Evolution of scientific production (2012- October 2020), articles and reviews

3.2 Most productive authors

The distribution of the top 20 authors who contributed most to the subject studied is shown, analysing the number of documents, their institution of affiliation and country, in addition to the H index (Table 1). The values of this last indicator were obtained from Scopus taking into account its coverage and therefore the possibility it offers of finding a greater number of authors and a wider knowledge of them. As information resulting from the analysis, it can be seen that the 20 authors are affiliated with institutions from various countries, mostly European, highlighting the participation of Spanish authors and the non-inclusion of authors from Latin America, even though Scopus was included as a source of databases with regional coverage.

The H index represents an indicator that shows, from two variables (production and citations) the performance of a researcher based on the distribution of citations in their articles published over a period of time. In the research, the H values of each author evidence the visibility of these within the research on the topic. Researchers with an H index greater than 50 are observed, which reflects the visibility translated into the number of highly cited works.

Table 1. Top 20 most productive authors

No.	Authors	ND	Institution	Country	H index
1	Jeong, J.S.	6	Universidad de Extremadura	Spain	13
2	González-Gómez, D.	5	Universidad de Extremadura	Spain	27
3	Hwang, G.J.	5	National Taiwan University of Science and Technology	Taiwan	57
4	Mclaughlin, J.E.	5	The University of North Carolina at Chapel Hill	United States	15
5	Cañada-Cañada, F.	4	Universidad de Extremadura	Spain	21
6	Chen, N.S.	4	National Yunlin University of Science and	Taiwan	38

			Technology		
7	Hinojo-Lucena, F. J.	4	Universidad de Granada	Spain	7
8	Long, Taotao	4	Huazhong Normal University	China	3
9	Sointu, E.	4	Itä-Suomen yliopisto	Finland	8
10	Waugh, M.	4	The University of Tennessee, Knoxville	United States	4
11	Zainuddin, Z.	4	The University of Hong Kong	Hong Kong	7
12	Broedel-zaugg, K.	3	Marshall University	United States	7
13	Cummins, J.	3	The University of Tennessee, Knoxville	United States	2
14	De Wever, B.	3	Universiteit Gent	Belgium	26
15	Fatima, S.S.	3	The Aga Khan University	Pakistan	11
16	Gillette, C.	3	Wake Forest School of Medicine	United States	12
17	Hafidi, M.	3	Université Badji Mokhtar - Annaba	Algeria	3
18	Hew, K.F.	3	The University of Hong Kong	Hong Kong	30
19	Hirsto, L.	3	Itä-Suomen yliopisto	Finland	6
20	Kinshuk	3	University of North Texas	United States	19

ND: number of documents in the dataset

3.3 Indicators of collaboration (2012 – October 2020)

The increase in collaborative work, generated by various scientific and social phenomena, has impacted on the development and quality of scientific systems and disciplines. With regard to the collaboration of authors, 75% of the papers were written in collaboration (two or more authors per published document) and 47% of these papers were published in collaboration with three or more authors, with the highest records in the period 2014-2018 (Table 2). This highly collaborative behaviour, which has tended to increase in recent years, is now common practice in most scientific disciplines. This panorama is generated by technological development, the interdisciplinarity present in the thematic areas, even in the Social Sciences and Humanities where practices have been marked by writing with little collaboration and with this change there is no doubt that the visibility and impact of the research produced will increase.

Table 2. Distribution of publications according to year and number of authors

No. of authors	Year of Publication									Total
	2012	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*Oct 2020*	
1	1	3	4	23	24	28	40	44	27	194 (25%)
2	0	2	4	18	28	33	45	46	43	219 (28%)
>=3	0	1	11	23	26	61	59	106	82	369 (47%)
Total	1	6	19	64	78	122	144	196	152	782

Figure 3 presents the three indicators of collaboration; index, degree and collaboration coefficient. At the top are the values of the collaboration index (CI) showing the

average number of authors per document. Thus, in 2014 and 2020, the highest values of the study period appear, with the average value of the whole set being 2.8 authors per document. The lower part of Fig. 3 shows the values of the degree of collaboration (CG), which range from 0 to 1. From 2015 onwards, there is a tendency for the CG to grow, which in 2020 reached the value of 0.82. This indicates that 82% of documents were written in collaboration (2 or more authors).

Finally, the collaboration coefficient (CC) proposed by Ajiferuke, Burrel & Tague [40] adds up the benefits of the CI and the CG which takes into account the difference between different multiple authorships. It also reaches its maximum value in the year 2020 with 0.54. The values of the CG reflect the complement of the inverse average weighted by the number of authors.
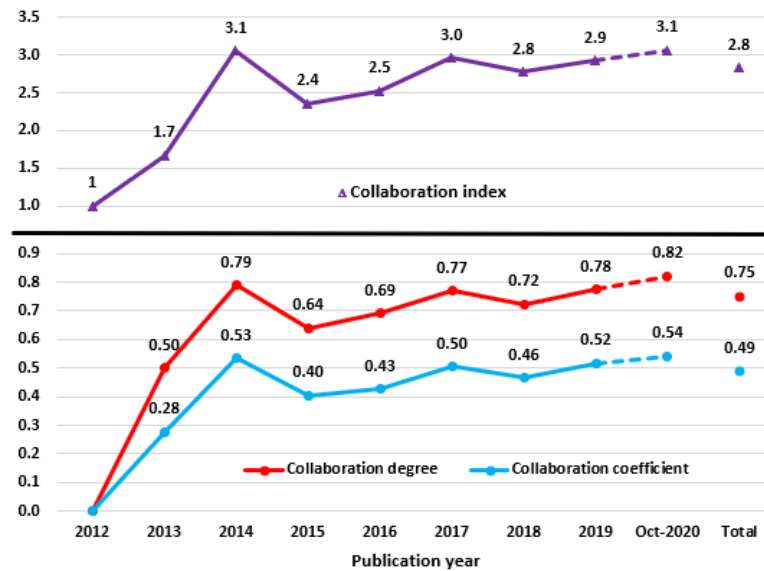

Fig. 3. Index, degree and coefficient of author collaboration

3.4 Keywords co-occurrence network

The co-occurrence analysis was performed with the 80 descriptors of more than 5 occurrences. Each node represents a keyword and its size is proportional to the total link strength of co-occurrence of keywords (Fig. 4). The overlay shows the use of the terms according to the average year of publication where the keyword appears, observing the evolution of the most important topics within the FC in higher education. The most frequent items published on average in 2017 are shown in blue, and those that appear in documents published on average in 2019 are shown in red. It is to be expected that flipped classroom is the most frequent keyword: however, items related to active learning, online learning, blended learning, among others, stand out.
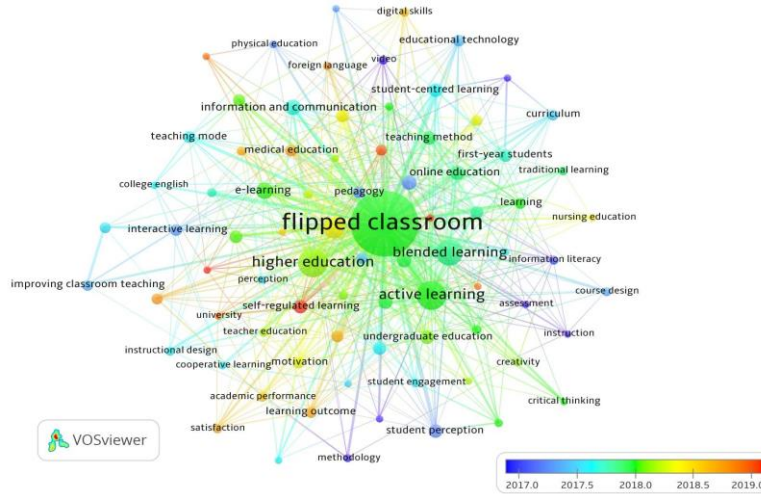
Fig. 4. Overlay visualization of keywords

For the analysis of the terms according to the frequency of appearance on the network, those with more than 10 appearances were taken into account, and 41 terms met this threshold. A significant difference is observed between flipped classroom with 569 appearances and the rest of terms with frequencies lower than 100 and a homogeneous amount between them, a trend that is related to being the base term of the analysis and the one used in the search equation (Table 3). The proximity of the FC to active learning, blended learning, e-learning, ICT, teaching method, among others, is evident. This could reveal that the implementation of the FC is accompanied by these important current trends. Figure 4 and Table 3 can be used as a reference for organising search and retrieval equations, or for identifying FC issues in future research.

Table 3. Most frequent keywords (n ≥10)

No.	Term	NO	No.	Term	NO
1	flipped classroom	569	22	mooc	16
2	active learning	90	23	interactive learning	15
3	higher education	90	24	medical education	15
4	blended learning	72	25	pedagogy	15
5	flipped learning	53	26	educational technology	14
6	e-learning	29	27	gamification	14
7	information and communication technology	25	28	motivation	14
8	online education	22	29	teaching mode	14
9	teaching	20	30	learning	13
10	teaching method	20	31	curriculum	12
11	student perception	19	32	improving classroom teaching	12
12	technologies	19	33	learning outcome	12
13	collaborative learning	18	34	engineering education	11
14	education	18	35	learning performance	11

| 15	self-regulated learning	18	36	peer learning	11
16	student-centred learning	18	37	problem based learning	11
17	undergraduate education	18	38	teaching/learning strategies	11
18	english as a foreign language	17	39	academic performance	10
19	english language teaching	17	40	information literacy	10
20	engagement	16	41	instructional design	10
21	first-year students	16			

NO: Number of occurrences

Similarly, an analysis of the clusters and their main descriptors was carried out which allowed the identification of thematic approaches revolving around FC in higher education (Table 4). Each cluster is made up of the keywords with the greatest strength among them according to the cooccurrence force of keywords obtained with the VOSviewer programme. Thus, the FC has to do with its use in the teaching of English as a foreign language (cluster 1), through active learning, autonomous learning, collaborative learning (clusters 2, 3 and 4), the use of ICT (cluster) and the improvement of academic performance (cluster 10).

Table 4. Distribution of clusters and their respective keywords

Cluster	Focus	Top of terms and their frequency of appearance	Size
Cluster 1	Flipped classroom, commitment and its use in teaching English	achievement levels (6), engagement (16), english as a foreing language (17), english language teaching (17), flipped classroom (569), flipped learning (53)	15 terms
Cluster 2	Active learning and creative thinking	active learning (90), assessment (6), course design (8), creativity (6), creative thinking (6), information literacy (10)	11 terms
Cluster 3	Autonomous, cooperative and experiential learning	autonomous learning (8), college english (6), cooperative learning (7), experiential learning (6), mooc (16)	8 terms
Cluster 4	Collaborative and online learning	collaborative learning (18), curriculum (12), e-learning (29), first-year students (16), internet/web-based learning (6)	8 terms
Cluster 5	Technology and digital skills	digital skills (9), educational technology (14), engineering education (11), medical education (15), nursing education (6), online education (22)	8 terms
Cluster 6	Higher education, technology and teaching methods	education (18), foreign language (7), higher education (90), information and communication technology (25), learning (13), teaching methods (20)	6 terms
Cluster 7	Academic performance and student perspective	academic performance (10), methodology (7), peer learning (11), student perception (19), student engagement (8)	6 terms
Cluster 8	Assessment and teaching and learning strategies	evaluation (8), improvement classroom teaching (12), instructional design (10), interactive learning (15), teaching/learning strategies (11)	6 terms
Cluster 9	Methodologies and student attitudes	attitudes (8), blended learning (72), case study (6), gamification (14), traditional learning (8)	5 terms
Cluster 10	Learning performance	content learning (6), data science (6), learning performance (11), physical education (7), team-based learning (9)	5 terms

3.5 Framework proposal

Based on some results of the bibliometric analysis and the background review, documents were chosen as the theoretical source for the proposal of a framework. The following criteria were applied: (a) papers by more productive authors, (b) results from the keywords co-occurrence network, (c) papers with more citations in the Web of Science and Scopus databases, (d) seminal studies by Bergman and Sams, and, (e) FC studies in the context of covid-19. This made it possible to propose a framework, a useful tool for higher education professors to implement FC in their classes either in the form of face-to-face, blended or online learning education (Fig. 5). From the literature reviewed, it can be seen that there is no specific methodology that indicates the steps to follow to replicate a FC, nor is there a list of tasks that can be followed to ensure good results [13]. The proposal has five components (Fig. 5) and is based on the studies of Bergmann & Sams [4], Bergmann & Sams [13], Jeong et al. [41], Kim et al. [20], Lo & Hwang [21], O'Flaherty & Phillips [33], Ożadowicz [16] and Hew et al. [18].
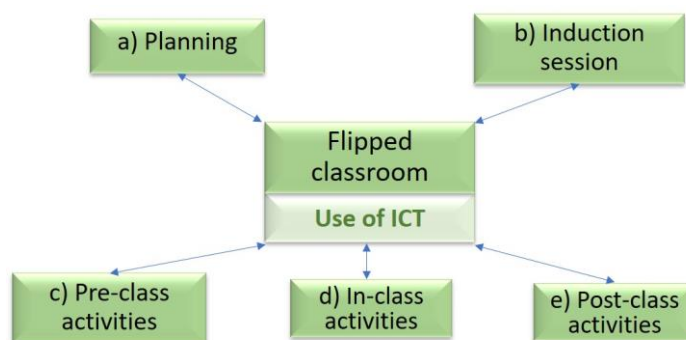
Fig. 5. Descriptive framework to implement a FC in higher education.
ICT: Information and communication technology.

Source: Own elaboration

Planning: This is the process prior to the development of the teaching/learning process under the FC approach. Among the considerations that the professor must take into account are; (a) to design the subject for the academic cycle knowing the type of pedagogy and didactics to be used, (b) to be trained in the use of ICT, which includes the university platform, computer programs to prepare teaching materials and to record the sessions, (c) to design the learning sessions considering the type of educational modality (classroom, blended or non-classroom) and, (d) to design the assessment system and the learning evidence with qualification headings or other assessment instruments.

Induction session on the first day of class: It is important that the student is clear about how to work under the FC approach, because the lack of clarity in the new role the student has can play against their learning process. Among the main activities of the professor are (a) presenting the syllabus and explaining the role of the students

and the professor under this methodology, (b) giving an induction on the use of technologies to be used, as well as teaching how to watch the videos and how to read the readings, (c) choosing forms of communication and organisation before, during and after the sessions. If it is online education, the professor must indicate and explain the type of web videoconference to be used. Several options are offered: Zoom, Google Meet, Cisco Webex, Microsoft Teams, among others, and (d) explain the evaluation criteria, and may accept suggestions from students.

Pre-class activities: For the professor, (a) seek and select up-to-date information on the subject of the class, (b) prepare and publish the materials (videos, readings, presentations, computer graphics, assessment rubrics), (c) communicate the availability of the pre-class material, and (d) prepare the self-assessment material for the students (through forms, video recording, Kahoot, Mentimeter or other means). Activities for the students, (a) review the class materials considering the guidelines given by the professor in the first session, (b) carry out the activities that allow them to check their self-learning, (c) generate questions about the revised material, and (d) take notes, record their questions and summarize what they are learning.

In-class activities: For the professor, (a) invite students to make a synthesis of what was seen in the previous session, (b) present the learning session in its global or joint form, (c) invite students to ask questions, (d) present the practical activities of the session (individual or group), here the importance of collaborative and team-based learning should be emphasized, and (e) give feedback on the topic and practical activities. For the students: (a) actively participate by asking questions, (b) participate in the hands-on activities, (c) after individual and/or group activities, they may respond to concepts in a collaborative way, (d) respond individually or collaboratively to session evaluations.

Post-class activities: Their use is not common in current FC practice, as additional work after class coupled with previous classes in the next class can produce a fatiguing effect on students. However, the professor can optionally: (a) offer the possibility of answering students' questions through forums from the platform, e-mails or other means of communication, and (ii) generate questions for students to reflect on the activities carried out.

4 Discussion and Conclusion

The purposes of this research were achieved which were to conduct a bibliometric analysis of FC in higher education and to propose a framework for implementing the FC. In this way, the article made several contributions to the scientific literature from the 782 refereed documents on the FC in higher education (2012-2020).

From the study period, the number of publications grew steadily in the sources analysed, this finding is in analogy with what [29], [31], [32] expounded. It starts 2012 with only one publication up to 152 documents in the year 2020 (October), this shows that FC research in higher education is in growing development. This increase is due, among other aspects, to the novel proposal of the methodology in the field of higher education, to the need to apply active methodologies of student-centred teaching and

learning, and in this last stage, in response to online learning due to the covid-19 pandemic. As for the top 20 most productive authors in the flow of information about FC, it is observed that Jeong, J. S. from the University of Extremadura, Spain is the most productive with 6 documents in the period analysed. If we analyse the affiliations and countries of the authors, we can see the participation of several countries coming from almost all the continents of the planet, which is one more sample of the importance of this subject at a global level.

Collaboration indicators show a growing interest in collaborative practices among FC researchers in higher education. The highest levels of collaboration are evident between 2013 and 2014, with a CG of 0.50 to 0.80, a CC of 0.28 to 0.53 and a CI of 1.7 to 3.1 authors per document. This phenomenon of collaboration not only reflects the need to generate local impact, but also responds to the motivation of complementing skills, obtaining recognition and visibility, increasing scientific productivity, among others [42]. With the development of science and the explosion of knowledge, nobody is an expert in everything, so scientific collaboration becomes a visible need in several disciplines [43], [44].

The analysis of the co-occurrence of keywords shows that the FC in higher education is of increasing interest for application in all professional areas with a specialised vision and close relation to active learning, e-learning, blended learning, information and communication technology, among other terms. This result is consistent with [31] who conducted a bibliometric study of the FC at all educational levels. Through this keywords analysis, the emphasis on FC research over the past few years has become apparent, as it responds to the current demands of education that go hand in hand with information and communication technologies (ICTs). The different clusters identified the main elements and approaches that are part of the FC and that complement its implementation in higher education.

The framework proposal in this paper was aimed at implementing the FC in higher education that could be taken into account to achieve better learning outcomes. The structure of the framework is based on five systematized components that include the design of the course, the induction of the first session with a clear presentation by the professor, who proposes mechanisms for clear connections between the class and outside the classroom. Then, the activities before, during and after the class were detailed by the students and the professor as a guide. This framework is easily adaptable to the various modes of education (face-to-face, blended or online learning) that act in complicity with the use of ICT [12], [20], [21].

In the light of the results, it is recommended that future studies evaluate this issue from other bibliometric methodologies such as co-citation, bibliographic coupling, analysis of networks of institutions and countries. It is also recommended that new research include FC studies with the altmetrics indicators to determine their behaviour and impact on social media. In addition, the study of the FC and its relationship to other active learning pedagogical models can be included. Finally, it is proposed to develop a methodology similar to this article to study the implementation of other educational models, such as gamification, design thinking, connectivism, project-based learning, among others.

5 Acknowledgement

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