Advances in Social Science, Education and Humanities Research, volume 315

International Conference on Pedagogy, Communication and Sociology (ICPCS 2019)

A Study on the Trends and Reflections on the Frontier Development of Flipped Education in the World: A Science Mapping Analysis

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***Abstract*—The recent technology development puts and inspires the flipped education in all education settings. For the flipped education, teachers usually prerecord teaching materials and post them online for students to learn anytime and anywhere so that teaching activities in classes can focus on student-centered collaboration and interaction. The flipped education is approved to effectively merge the traditional homework with class teaching for better quality with interaction and collaboration. This article first discusses the method of science mapping analysis and its main algorithms, taking the Citespace software as an example to give the best fitted result. Then, the literatures from 1991 to 2017 in the Web of Science are presented and discussed. At the same time, national or institutional research trends and frontiers are analyzed on the basis of collaborative network and timeline. Furthermore, this article discusses the research contents in detail through the literature co-citation analysis. From the two dimensions of centrality and citation times, the 11 clusters generated by the software are then integrated into two categories. Major findings of this study include: (1) regardless of the volume of publications or the impact of journals, the United States continues to lead the research frontiers of flipped education in world, followed by Australia, China, and Taiwan; (2) in the previous research, most scholars focus on the differences between flipped education and traditional education, and declared that the students who learn in the flipped classroom are significantly better than in the traditional classrooms; and (3) in the current research, researchers begin to further study which features of flipped education can significantly improve academic performance, focusing on the differences in students' academic performance comparing different methods of flipped education.**

Keywords—flipped education, flipped classroom, inverted classroom, science mapping analysis, CiteSpace

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Fund Project: this work was supported by two grants. One is about reform of teaching in higher education (SXSKG2017085) from Shaoxing Education Bureau. The other is the 13th five-years plan of national business education grant (SKJYKT-1703) from China Council for the Promotion of International Trade Commercial Sub-Council.

I. INTRODUCTION

Higher educational institutes are generally experiencing high pressure due to the rapid changes in technologies and social development, and applying ubiquitous internet for better teaching. Recently, the flipped or inverted education consequently become popular approaches in Taiwan, which includes pedagogic theory and teaching practices. The Ministry of Science and Technology in Taiwan set high priority to the development of flipped education research by supporting lots of project funds to improve the curriculum development. The purpose of this science mapping analysis was to provide an overview of relevant research frontiers and trends demonstrating the global use of flipped education, identifying major areas of research activities concerning inverted education and the dynamic transition from one specialty to another one.

In the spring of 2007, Bergmann and Sams began to record the live chemistry lessons using screen capture software, then posting their lectures online to students at Woodland Park high school [1]. They did not come up with the term flipped education, but they are the pioneers to apply flipped classroom to daily teaching and promote flipped education worldwide. Since the practice in Woodland Park, more and more scholars have begun to pay attention to the study of flipped education. Taking United States for example, the number of articles published on the Web of Science reach to 324 from 1991 to 2017, accounting for almost 70% of the total number of publications. After 2012, Australia, China and Taiwan have also begun to research.

In the previous research, most scholars focus on the differences between flipped education and traditional education, then, find that the students who learn in the flipped classroom are significantly higher than the traditional in the academic performance [1-4]. Bergmann and Sams are chemistry teachers in a high school, which impact the early researches mostly applying to science education, such as physical chemistry, biochemistry, nursing, pharmacy, veterinary education, and application software education [4-8].

The concept of flipped education is not really novel new because teachers have utilized interactive technologies to prepare instructions for long. Since many studies approved the flipped classroom instructional approaches could impact students' performance significantly, the next stage of the flipped education evolution should focus on what features of the inverted classroom best yielding benefits for students and teachers [9].

II. Conception and Application of Flipped Education

It is firstly referred to as the inverted classroom, which means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa [16]. Until to 2012, although Bergmann and Sams did not come up with the term flipped education, but they firstly defined the concept of flipped classroom, which is traditionally done in class is now done at home, and that which is traditionally done as homework is now completed in class [1].

For Woodland Park high school students, they generally would spend the 25 minutes doing a warm-up activity in the traditional classroom. But, in the flipped model, the time is decreased to 5 minutes, because students have viewed the lecture video [1]. Unlike the classic high school where students watched only lectures prior to class, undergraduate or graduate students need view PowerPoint videos and read textbook materials and approximately 2 to 4 current journal articles. In the renal pharmacotherapy course, students' performance on the final examination significantly improved, and students are positive to the flipped classroom [2]. In a pediatric course, Critz (2013) revealed learners' satisfaction with flipped classroom approaches and improved previous uncomfortable contents [6].

Nevertheless, flipped education are not really new because teachers have applied interactive technologies to instruction preparation for over 20 years [3]. Since many studies have shown the flipped classroom instructional model benefitting students' performance significantly, we should get an explicit expression of what features of the flipped education facilitating students and instructors [9].

The flipped classroom strategy is highly related to the performance of students, and therefore teachers need better preparation of flipped classroom strategy [10]. Kim (2014) designed four sections in the student survey to research three flipped classes from different majors and proposed nine design principles of student-centered learning for the flipped classroom [9]. On the other hand, given to economic restraints on behalf of universities, we'd better design cost-effective flipped classroom [11]. If the objective of curriculum design is efficiency and scalability, then the flipped and simulation-based curriculums can be considered, on accounting of both offering alternatives that can be implemented with few faculty and technology resources [8].

III. Research Methods

The input data of our review is generated by a combination of the results from multiple topic search queries to the Web of Science, which include two topic terms, "inverted classroom" and "flipped classroom". The timespan published is from 1991 to 2017, totally leading to 581 records. We visualize and analyze the dataset with a new version of CiteSpace (5.3.R3). CiteSpace has been continuously developed to meet the needs for visual analytic tasks of science mapping [12-14].

It takes bibliographic records as input data and models the intellectual structure of research domain in terms of a synthesized network based on a time series of networks derived from each year's publications [15]. n this study, we mainly focus on the document co-citation analysis within the period from 1991 to 2017.

Comparing the minimum spanning tree and pathfinder algorithms, we use modularity and mean silhouette to analyze the results of 581 articles. It is found that the minimum spanning tree algorithm has higher modularity value, but the mean silhouette is lower. The modularity obtained by the pathfinder algorithm are above 0.6 and the mean silhouette are above 0.3. Therefore, the sixth algorithm is used for literature co-citation analysis.

TABLE I. The method of Citespace

Number	Method			Modularity	Mean Silhouette
	Algorithm	Pruning			
1	minimum spanning tree	pruning sliced networks		0.673	0.315
2	minimum spanning tree	pruning the merged network		0.869	0.241
3	minimum spanning tree	pruning sliced networks	pruning the merged network	0.870	0.233
4	pathfinder	pruning sliced networks		0.653	0.308
5	pathfinder	pruning the merged network		0.784	0.332
6	pathfinder	pruning sliced networks	pruning the merged network	0.788	0.335

IV. Research findings and discussions

A. Collaborative network analysis of countries, regions and institutions

Citespace uses tree rings generated from two indicators, centrality and count, to identify and measure the importance of the countries, regions and institutions. The purple circles are highlighted to mean that the label showed owns the powerful impact. Numbers in the figure are the clusters generated through the normal clustering method. Details about these clusters will be discussed in the next section.

The size of tree rings in the network reflects the amount of articles issued by the countries or institutions.

As shown in the figure 1, the main research results are from the United States, covering almost every cluster category, with 324 articles published, followed by Australia, China and Taiwan. Although Taiwan does not present a purple circle in the figure, its number of publications ranks second among countries or regions, reaching 36 articles.

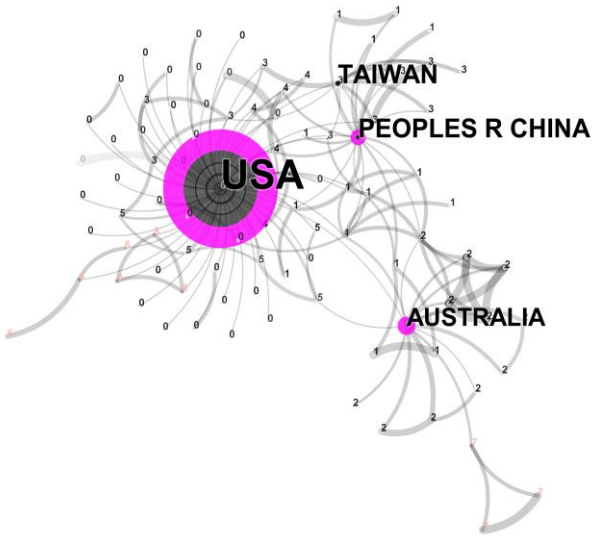

Fig. 1. Collaborative network of countries, regions and institutions

From the table below, the top ten institutions in the finals are the University of Northern California and the National Taiwan Normal University. Taiwan's flipped education study began in 2015, actually the latest in the top ten countries or regions, but the latecomer comes to the top 3 in just three years. It can be seen that both the Taiwan Ministry of Science and Technology and the Ministry of Education, as well as Taiwanese scholars, attach great importance to the study of flipped education recently.

TABLE II. THE RANKINGS OF ARTICLES COUNT

Count	Centrality	Initial Year	Institutions | Countries or Regions
324	1.51	2000	USA
36	0.10	2015	TAIWAN
35	0.32	2014	PEOPLES R CHINA
32	0.44	2012	AUSTRALIA
22	0.09	2014	CANADA
16	0.00	2014	TURKEY
12	0.04	2015	SPAIN
11	0.04	2016	ENGLAND
9	0.01	2013	Univ N Carolina
7	0.00	2016	Natl Taiwan Normal Univ

B. Timeline analysis of countries, regions and institutions

Through collaborative network analysis, we can quickly understand from a macro perspective which countries, regions or institutions are studying this topic, but it is difficult to analyze from the vertical time series and the specific subdivisions. CiteSpace's timeline analysis which is like panel study and cohort study, addresses the shortcomings of collaborative network analysis. After visual clustering through timelines, all articles are divided into nine clusters, named according to their respective research domains.

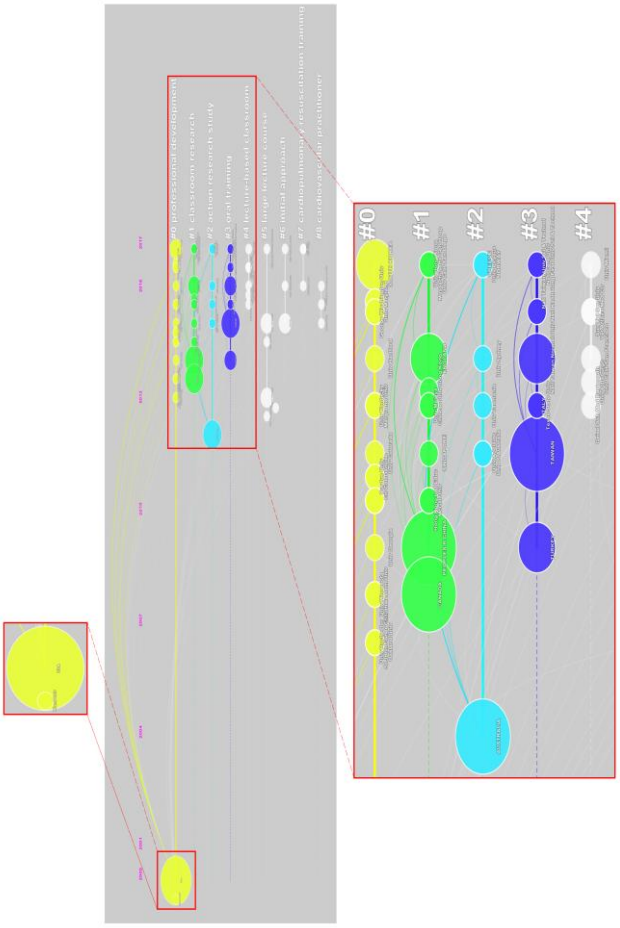

Fig. 2. Timeline of countries, regions and institutions

Each node means that a country, region or institution publishes some articles in this year or period. The colors of each node in the figure represent different clusters, and the size of node depend on the amounts of articles in that country, region or institution. Given to the 9 clusters totally, we just analyze the largest top five clusters. In 2000, the University of Miami in the United States was the first institution to conduct inverted classroom research [16]. Since then, until the 12 years of 2012, worldwide scholars have few published relevant articles on Web of Science, like yellow timeline the Cluster#0 during 2001 to 2013. Since 2013, colleges and universities in the United States have restarted the study of flipped education, such as University of Rochester, Oakland University, University of Minnesota,

Northwestern University and so on. Most of American scholars preferer to research majors of diverse subjects or 'professional development'. Australian scholars do action research since 2012, such as University of Adelaide, University of South Australia, University of Tasmania, and University of Sydney. The main research areas in Canada, China, Singapore and Hong Kong are concentrated in 'classroom research', which includes the concept, feasibility and other fundamental research. The main research areas in Turkey, Taiwan and Italy are 'oral training', such as language courses, language training, and K12 education.

C. Co-cited analysis of references

The amount of articles from Web of Science are 581 totally, including 10,422 references. Thus, if we still use the traditional clustering method used above, the value of modularity and mean silhouette of clusters is not best. Through the pathfinder algorithm and two pruning ways, this study finds the visualization of big data is relatively more distinct than the normal clustering method. And, Modularity is high to 0.784, and mean silhouette is 0.332, which mentioned in the table 1. Finally, Citespace generates 11 clusters labelled with red fonts in the figure 3. But, we will mainly discuss the four largest clusters in the table 3. All sizes are greater than or equal to 20, and silhouettes are greater than 0.7. Therefore, we believe these four largest clusters basically are able to represent the population of 10,422 references.

Each node indicates a reference, which is linked by the diverse colorful lines. The colors of lines belong to different clusters. Once the node is labelled with a purple circle, it means that this node is a key node in the co-cited references network. In the figure 3, there are 26 outstanding references labelled with a purple circle totally. And, the thicker the circle, the more important it is. Thus, in the view of centrality, the most important reference is written by Galway L. P. (0.37), followed by Kim M.K. (0.32), Butt A. (0.21), Kong S.C. (0.20). The size of tree rings with yellow shadow in the network reflects the amount of this reference cited. From the size of tree rings, the most frequently cited reference is from Bergmann J. (111), Mclaughlin J.E.(80), Strayer J.F.(75), Kim M.K.(45). The key nodes with high co-cited counts–low centrality mainly concentrated in Cluster #0 and Cluster #1, representing these references are relatively earlier and biased in basic theory. The key nodes with low co-cited counts–high centrality mainly concentrated in Cluster #2 and Cluster #3, representing these references are relatively late and biased in application. Therefore, we use the blue rectangle to indicate high co-cited counts—low centrality zone, and the remaining areas represent low co-cited counts—high centrality zone. It becomes easy and direct to observe that, in the blue rectangle, the yellow tree rings are dense, and the purple circles are less, and in the remaining zone vice versa.

TABLE III. THE FOUR LARGEST CLUSTERS OF CO-CITED REFERENCES OF THE NETWORK

Cluster ID	Size	Silhouette	Label (MI)	Label (LLR)	Mean (Cite Year)
0	28	0.918	application software education, physical chemistry, synthesis, etc.	active learning environment	2014
1	21	0.739	veterinary education, individual readiness assessment, teaching and learning, etc.	fundamental concept	2012
2	21	0.972	student ratings, genetics, emergent pedagogies, etc.	fcpi score	2014
3	20	0.805	students and embedded assessment, self-regulated learning co-regulation and shared regulation, blended, etc.	learning attitude	2012

1) High co-cited counts—low centrality zone: conceptualization stage

In this zone, most of references defined the concept of flipped classroom (also known as the reverse, inverse, or backwards classroom). Thus, we can find that the flipped classroom which is traditionally done in class is now done at home, and that which is traditionally done as homework is now completed in class [1]. In the inverted classroom, teachers prerecord lectures and post them and other martials online for students to learn so that class time can be undertaken to student-centered collaborative and interactive learning activities [5]. Through using diverse modern technology, it makes a sustainable, reproducible, and manageable learning environment, like the LLR label mentioned in Cluster #0.

The book *Flip Your Classroom Reach Every Student in Every Class Every Day* by Bergmann and Sams (2012) is an important member of this zone, labelled the largest size of yellow tree ring. These two authors are teachers in chemistry department of high school, which impact the early researches are mostly applied to science education, such as physical chemistry, biochemistry, nursing, pharmacy, veterinary education, and application software education, like the MI labels mentioned in Cluster #0 and #1. And, the empirical experiments are generally designed to the comparison between traditional format and flipped classroom format. The object of flipped classroom is established in this zone, which sometimes is called conceptualization stage [17]. While they find the academic performances of student are improved in the flipped classroom, the results still fall short of explicit description of what features of the inverted classroom yielded benefits for students and teachers [9].

2) Low co-cited counts—high centrality zone: application stage

Flipped education are not new because teachers have

relied upon interactive technologies to prepare instructions about 20 years ago. Indeed, the flipped education which was named blended learning, has arisen within a broader development in higher education that has seen an increased mixture of face-to-face classroom experiences with online learning experiences [3]. Since many studies have shown the flipped classroom instructional model impact student performance significantly, the next stage of the evolution of a flipped education is usually characterize by the development of research instruments, or tools [17]. Thus, we call the low co-cited counts—high centrality zone is in the application stage.

In the upper right area of figure 3, many articles of scholars are too outstanding to escape special attentions. The flipped classroom strategy is highly related to the performance of students, and therefore need teacher development for their better preparation of flipped classroom strategy [10]. To get an explicit expression of what features of the flipped education yielded benefits for students and instructors, Kim (2014) designed four sections in the student survey to research three flipped classes from different majors and proposed nine design principles of student-centered learning for the flipped classroom. Actually, lots of the MI labels of Cluster #2 and Cluster #3 are student-centered, such as student ratings, student assessment, and self-regulated learning in the table 3.

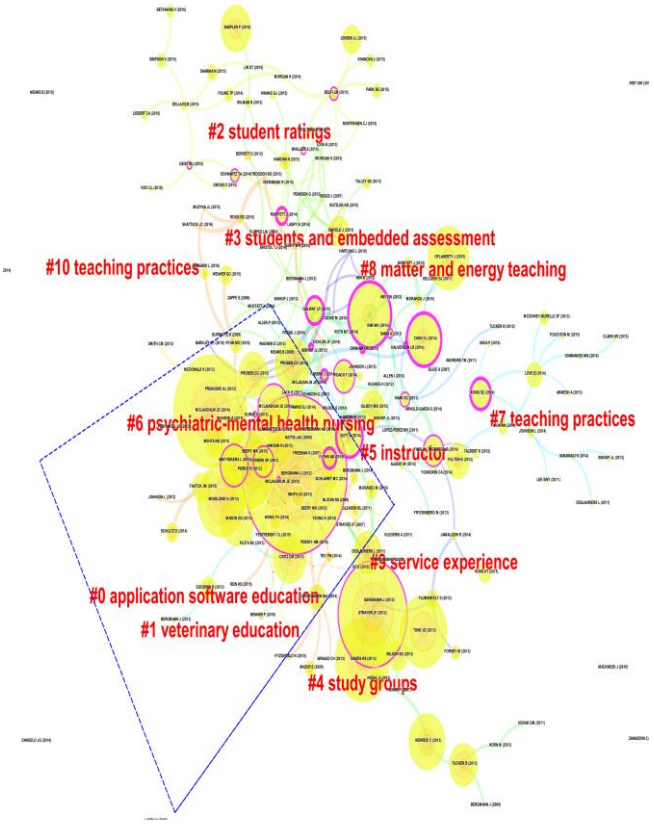

Fig. 3. Network of co-cited references

V. CONCLUSIONS

As Strayer 2012 noted, the concept of the inverted classroom is the regular and systematic exploitation of interactive technologies in the learning process. On the basis of significant effects of flipped education on students' learning achievement, the subsequent research should go further to the features and\or technologies which can significantly apply in the flipped classroom. We finally drew the following four conclusions:

(1) The flipped education and consequently innovative teaching approaches have been becoming the current trends in this competitive world for the effective and student-centered education. This flipped pedagogy emphasizes student-oriented educational philosophy and practices, including individualization, inspiration, pragmatism, and teachers' scaffolding and on-site consultation.

(2) The flipped education has been consistently approved to significantly improve students' learning achievement and future inspiration in their future professional careers more than the conventional teaching approaches.

(3) The emergent issues challenge current professionals in educational settings moving into the innovative and inspiring era and improving their teaching materials and interventional approaches. Teachers in all levels of educational setting should take the flipped education concepts to revitalize their teaching enthusiasm for improving educational quality in the realistic school scenario in order to effectively and realistically implement the flipped education.

(4) The faculty development programs are subsequently suggested to be widely undertaken, employing the flipped educational perceptions, for teachers' capabilities of developing appropriate curricula and effective instructional strategies for this educational reform movement from elementary to higher education.

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