A Bibliometric Review on Chemistry Education: Bodies of Research, 1980-2020

Sarifah Fauziah Syed Draman[1*], Norzila Mohd[2]

[1 2]School of Chemical Engineering, College of Engineering, Universiti Teknologi MARA, Cawangan Terengganu, Bukit Besi Branch, 23200 Dungun, Terengganu, Malaysia
sfauziah@uitm.edu.my
norzi085@uitm.edu.my
[*]Corresponding Author

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Abstract: Over the four decades, there has been sustained research activity in chemistry education. However, in terms of bodies of research, only a few different views were recorded. Thus, this study aimed to examine the trend bodies of research on chemistry education over the past 40 years (1980-2020) by using bibliometric analysis. Data based was collected from Scopus-indexed documents based on the 'title' search results. A total of 1041 finalized documents from various research types were used for further analysis. Two software (Harzing Perish and VOSviewer) were used to complete the bibliometric review using standard bibliometric indicators. This study found 12 types of documents published is related to chemistry education. 57 % of the total publications are from articles. The highest source type is journals (81%). Then, the growth of the related publications has risen gradually. English is the top language used in publications. The United States is ranked first in productivity published documents when an analysis by country is done. Citation analysis results can identify key authors and documents that designed the progress of this review. This analysis is used to determine the intellectual structure of the chemistry education knowledge base. In conclusion, this review delivers a better understanding of the development trends in chemistry education bodies of research over the past 40 years. Furthermore, the review result can also offer a reference for future research.

Keywords: Chemistry education, Citations count, Scopus, Trend, VOSviewer

1. Introduction

Chemistry education plays a vital role in enhancing teaching, research, and development to ensure that students are equipped with adequate knowledge in schools, colleges, or universities. Many studies have been carried out and educational policy papers presented for the learning of chemistry. Understanding abstract concepts, symbols, terminologies, and theories are all part of chemistry education (Zulkipli et al., 2020). Some studies found that students are not interested in chemistry learning since they do not notice that chemistry and chemistry education is related to themselves and society (Khanam, 2018). Therefore, changing teaching methods and appropriate chemistry instructors' training within many modes focused on chemistry education bodies of research. The primary chemical education studies aim to improve classroom lectures, demonstrations, and laboratory activities. There are four different views of chemical education studies. The first view is from the practitioner's perspective. A self-identified group of chemical educators becomes the second view (Coppola, 2007). Then, the third and fourth views are from the group of chemical education research (CER) (Taber, 2019) and Scholarship of Teaching and Learning (SOTL) (Hutchings & Shulman, 1999), receptively.

The practitioner's perspective is the individuals who are responsible for teaching chemistry. Usually, they are teachers, instructors, or professors. They have also defined chemistry education through their actions (Moon et al., 2017). Examples of self-identified chemical educators' groups are faculty members and instructors who oppose declaring their primary interest in a typical laboratory research area. Those researchers are interested in contributing suggestions, essays, observations, and other descriptive reports of practice into the public domain through journal publications or books. Discoveries completed by them generally about effective teaching and learning (Heady et al., 2001). CER practitioners tend to study others' teaching practices compare to their classroom practices (Wink, 2020). Chemical education research is typically carried out *in situ* using humans from secondary and post-secondary schools as subjects in a study. Chemical education research employs both quantitative and qualitative data collection methods. The fourth view group is SOTL scholars, who focused more on how teachers/educators can improve their fields' expertise (Coppola and Jacobs, 2002). Their research also reported the developed pedagogical knowledge and better teaching for novice students in the area or enabling their learning. It also covers the study and implementation of more modern teaching methods, such as active learning, cooperative learning, problem-based learning, etc. (Chen et al., 2020). Based on that, there is a constant need to update teachers'/educator /educators' skills in teaching chemistry. Therefore, chemistry education bodies of research address this need. According to Yeoh (2017), four tendencies were identified regarding chemical education. The trends focus on learners or student-centeredness, a multi-disciplinary approach to solve present and future problems, develop scientific literacy, and move away from the authoritarian style/methodology to a democratic style emphasizing active learning for individual and collaborative group work. In order to observe the evolution of the scientific literature and identify specific characteristics of the related knowledge on chemical education, a bibliometric analysis was applied in this review article. Evaluating the impact of research can offer an important perspective in understanding a discipline (Ye et al., 2015).

Bibliometric analysis techniques have steadily gained popularity as one approach in reporting research trends/patterns (Ahmi & Mohamad, 2019). The bibliometric study employs mathematical and statistical tools to evaluate the published materials' quantity and quality to observe a specific research area. The bibliometric analysis can give perspective on the knowledge distribution of the focused literature across these journals and their relative impact, including identifying key scholars and documents within a field of research (Hallinger and Kovačević, 2019). The most common aspects of bibliometrics analysis are publication classification, citations, authorship details, publication impact, and country of focus (Ahmi et al., 2020). Thus, these indicators also were focused on in this bibliometric review. The purpose of this review is to gain an empirically based perspective on the evolution of the chemical education bodies of research over four decades.

2. Method

Data used for this study has been obtained from the Scopus database as of June 2021. In order to get reliable and accurate results, a complete search was carried out using [TITLE (chemistry AND education) AND (LIMIT-TO (PUBYEAR, 2020-1980). The keywords used were "chemistry" and "education" to search for a relevant article because it represents its study's relevant topic. Based on the article's title, 1041 documents have been obtained to conduct the bibliometric analysis. In exploratory bibliometric research, there are some tools available to discover the data. Microsoft Excel analyses the published materials' frequencies and designs the appropriate chart and graph for this paper. Meanwhile, VOSviewer software has been used to construct and visualize bibliometric networks. Harzing's Publish and Perish software to calculate the citation metrics and some of the other frequencies.

The study addressed four specific research questions.

Research Question 1: What is the capacity of the document and source type of the chemical education journal literature published between 1980 and 2020?

Research Question 2: What are the growth path and geographic distribution of the chemical education journal literature published between 1980 and 2020?

Research Question 3: What journals, authors, and articles have shown the most significant citation impact over the past four decades?

Research Question 4: What fascinating topic gives the most incredible attention from chemical education scholars between 1980 and 2020?

Overall, this study has implemented the PRISMA guideline, and the detailed flow chart of the research framework is shown in Fig. 1.

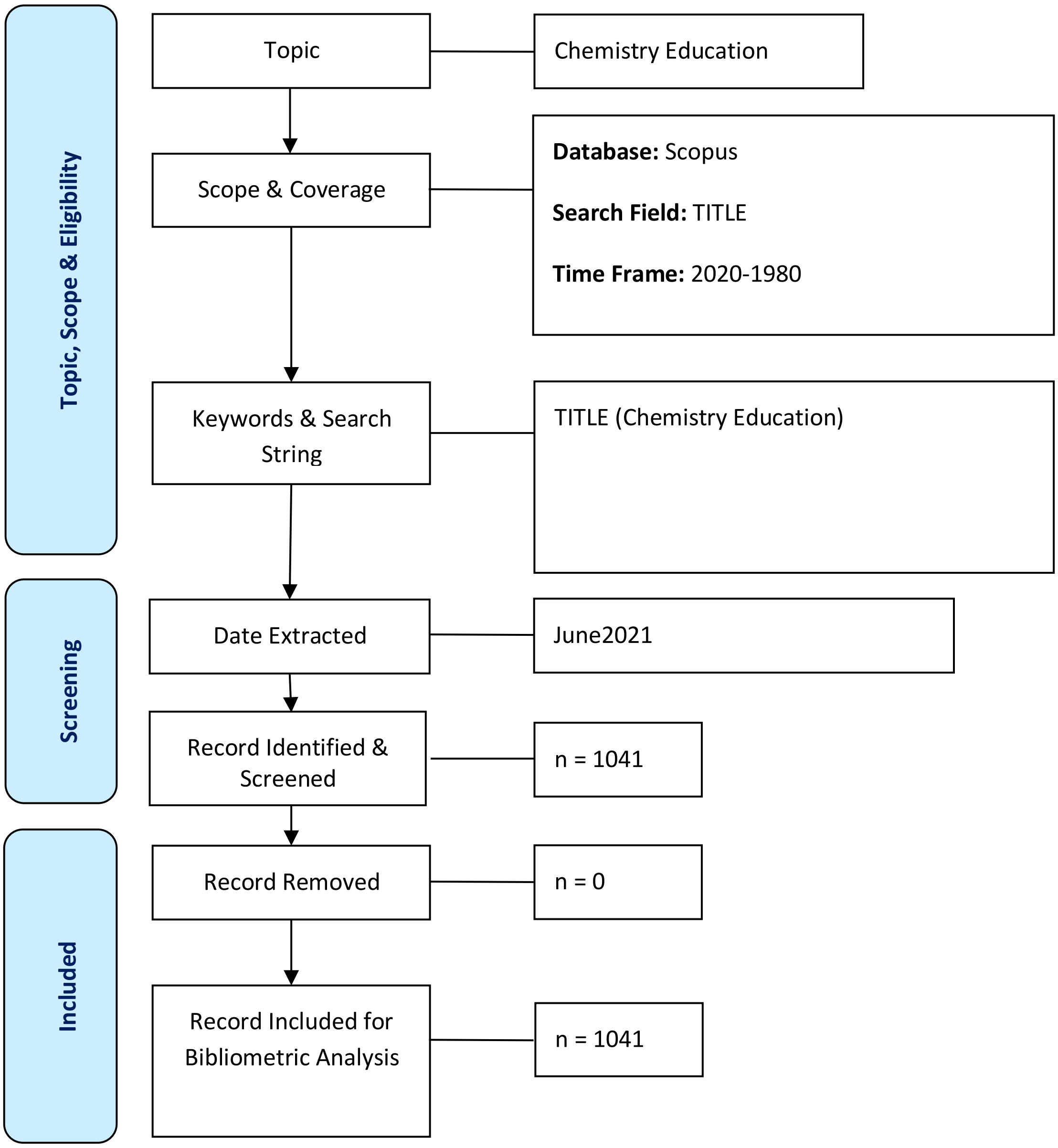


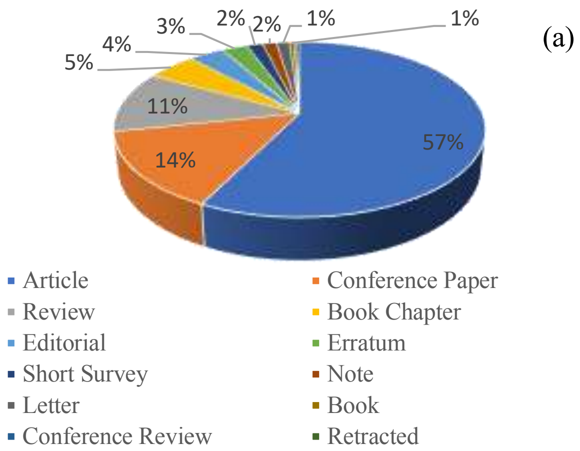
Fig. 1 PRISMA Flow Diagram (Ahmi & Mohamad, 2019)

2.1 Findings and arguments

According to (Ahmi et al., 2020), an article's title should integrate information to encourage readers' attention since the title is the first element that readers observed. The extracted academic works analysis includes document and source types, documents per year, language, subject area, keywords analysis, country productivity, and authorship. Most of the results have presented as frequency and percentage. Meanwhile, citation analysis is reported as citation metrics.

2.1.1 Document and Source Types

This study found 12 types of published documents related to chemistry education, as shown in Fig. 2 (a). At the same time, the journal was the leading category of publication source type (Fig. 2 (b)).



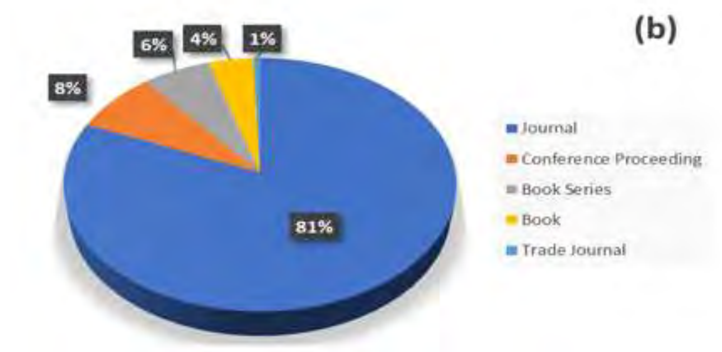


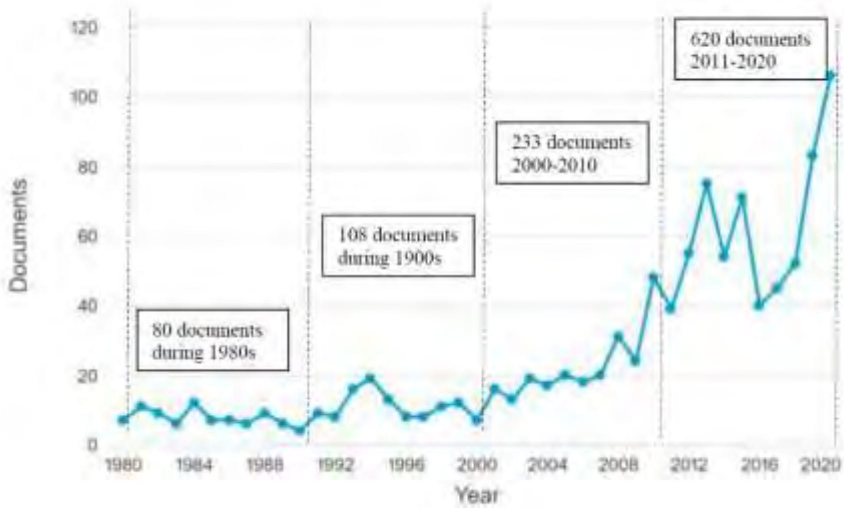
Fig 2. (a) Document type and (b) Source Type of published academic works.

2.1.2 Analysis of descriptive trends in the chemistry education knowledge base

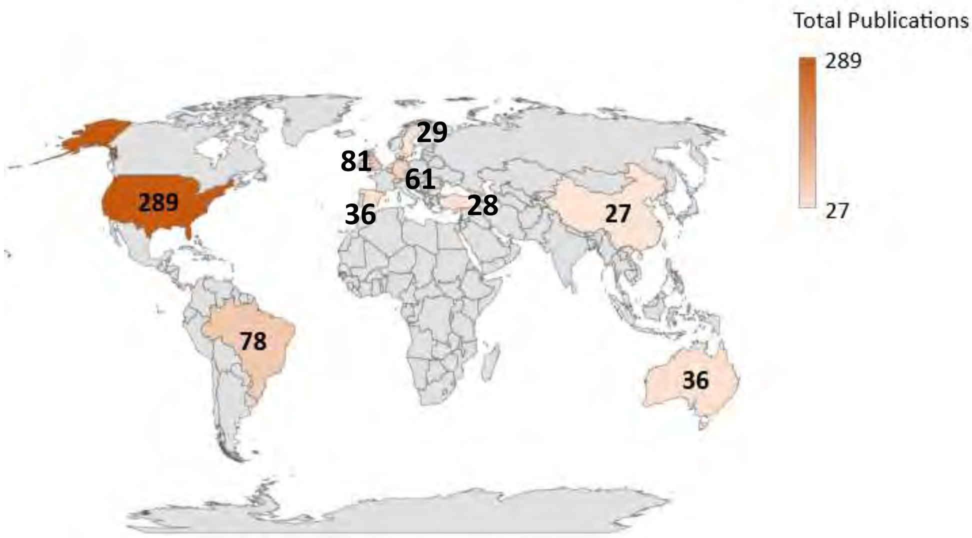
The 1041 Scopus-indexed documents published over the past 40 years represent a rising knowledge base on chemistry education. In chemistry education research, awareness developed slowly during the 1980s and 1900s with 80 and 108 documents. The basic bibliometric analysis uses descriptive statistics to document trends within a body of knowledge. For example, (Hallinger and Kovačević, 2019) used bibliometric content analysis to document trends in topics and research approaches used in the educational administration.

Fig. 2 (a) shows that the number of publications grew year by year with 233 documents during the 2000s. Flaherty (2020) reported that there had been a flow of research on chemistry students' attitudes, self-efficacy, self-concept, expectations, values, interest, motivation, effort beliefs, and achievement emotions in the past twenty years. Finding this research showed how students feel when learning chemistry and how this may influence how they perform. About 60 % of literature was published between 2011 and 2020, leading to the conclusion that this is emerging literature. Fig. 3 (a) The number of publications in chemical education increased starting in 2012 and achieved 71 publications in 2015. The industrial revolution (IR 4.0) also begins in 2015. The trend of research change to the approaches related to pedagogical integration, e-learning, and virtual classrooms/manipulation that involved enhanced technology towards IR 4.0. As an example, Ramos et al. (2016) reported about hands-on and virtual laboratories to undergraduate chemistry education that a pedagogical integration. The changes in the approach of research might explain why the number of publications that particular year decreased. Then, research in learning chemistry related to IR 4.0 increased. Faruku & Corrienna (2020) have cited a few studies related to the education system towards IR 4.0 in their article about integrating augmented reality in learning chemistry. Maria et al. (2018), cited in Faruku & Corrienna (2020), reported current Malaysian higher education system trends towards IR 4.0. Meanwhile, Tanriogen (2018) stated the possible effects of IR 4.0 on the Turkish educational system

Fig. 3 (b) shows that most of the publications in chemistry education are authored by American-European researchers. Previous researchers also reported the same pattern when reviewing sustainable construction research (Udomsap & Hallinger, 2020).



(a)



(b)

Fig 3. (a) The growth path of chemistry education publications, 1980-2020 (n = 1041); (b) Chemistry education bodies of research from 4ountries with more than 20 publications, 1980-2020

2.1.3 Citation Analysis

Citation analysis recognized the key authors and documents that designed the progress of the review. The output of researchers has been measured by the number of citations and citations per year. As shown in Table 1, there were 601 authors, with 2.39 authors per paper. As shown, there are 6671 citations reported in 40 years (1980 – 2020) for 1041 retrieved articles with an average of 162.71 citations/year. Meanwhile, Table 2 reveals the top 10 most cited papers. It has based on the number of times quoted as per the Scopus database. This indicator is standard in bibliometric analysis to analyse the significant impact of the focus research field reported by previous researchers in their focus field (Ahmi et al., 2020, Pirri et al., 2020).

Table 1. Citations Metrics

Metrics	Data
Publication years	1980 - 2020
Papers	1041
Citations	6671
Years	40
Cites/ Year	162.71
Cites/ Paper	6.47
Cites/ Author	3908.02
Papers/ Author	601.63
Authors/ Paper	2.39
h index	38
g index	59

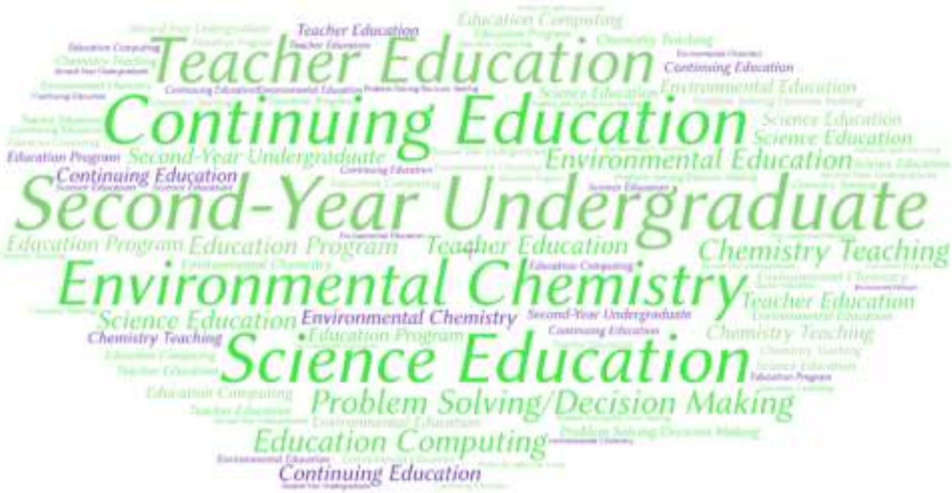
Table 2. Highly cited articles

No.	Authors	Title	Year	Cites	Cites Per Year
1	D. Gabel	Improving Teaching and Learning through Chemistry Education Research: A Look to the Future	1999	284	12.91
2	K.S. Taber	Revisiting the chemistry triplet: Drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education	2013	168	21
3	A. Bulte, H. Westbroek, O. de Jong, A. Pilot	A research approach to designing chemistry education using authentic practices as contexts	2006	149	9.93
4	B. Dalgarno, A.G. Bishop, W. Adlong, D.R. Bedgood Jr.	Effectiveness of a Virtual Laboratory as a preparatory resource for Distance Education chemistry students	2009	139	11.58
5	M.K. Seery	Flipped learning in higher education chemistry: emerging trends and potential directions	2015	132	22
6	M. Burmeister, F. Rauch, I. Eilks	Education for Sustainable Development (ESD) and chemistry education	2012	129	14.33
7	K.S. Taber	An alternative conceptual framework from chemistry education	1998	125	5.43
8	M. Limniou, D. Roberts, N. Papadopoulos	Full immersive virtual environment CAVETM in chemistry education	2008	119	9.15

9	Y.-C. Chen	A study comparing the use of augmented reality and physical models in chemistry education	2006	88	5.87
10	H.-D. Barke, A. Hazari, S. Yitbarek	Misconceptions in Chemistry: Addressing perceptions in chemical education	2009	82	6.83

2.1.4 Keywords Analysis

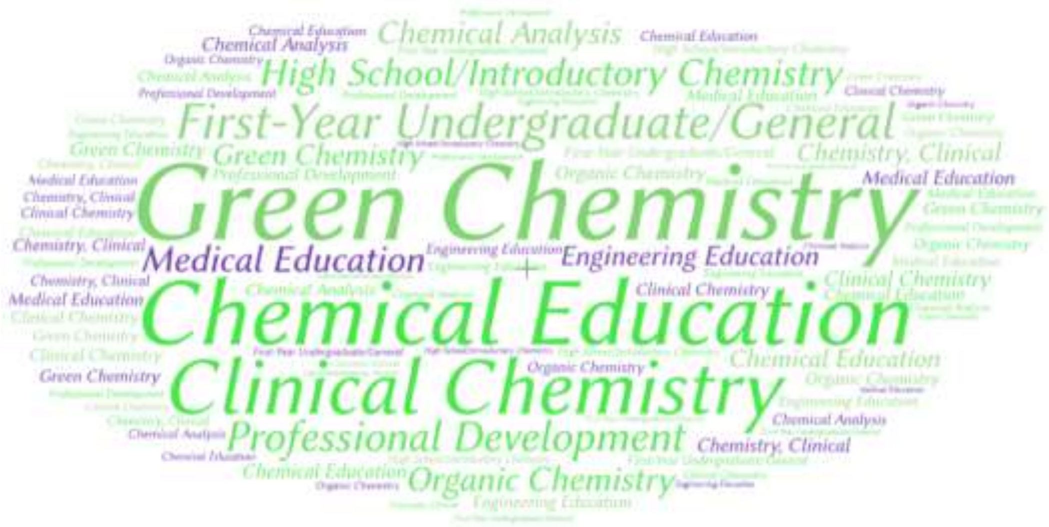
Keywords summarize the key contents of the paper. Useful information, such as objectives, methods, and perspectives, can be obtained from the keywords of a publication (Tian et al., 2018). Therefore, the frequency analysis of keywords is key to the investigation of hot topics and developments in the field (Wang et al., 2018). For this study, keywords were analyzed based on clustered years (Fig. 4). It can be shown that the most emerging terms in the early stages of study (1980-1989) were second-year undergraduate, teacher education, scientific education, and environmental chemistry. Whereas, from 1990 to 1999, the focus of chemistry education research shifted to higher education. The most exciting discovery was the word "e-learning." In the 1990s, educators begin to adopt e-learning methods in chemistry lessons. For millennia era, the only difference one could highlight is the increase in the size of the keywords' chemical education'. Besides, the terms' green chemistry' and 'clinical chemistry' indicate a different paradigm of chemistry education in which it has been expanded to include sustainable and clinical research. Finally, the most emerging keywords from 2011 to 2020 are curriculum, students, and teaching. These keywords demonstrate that the current researcher's focus in chemistry education is on the curriculum and the best teaching method beneficial to students. Therefore, future research can be conducted based on these findings.



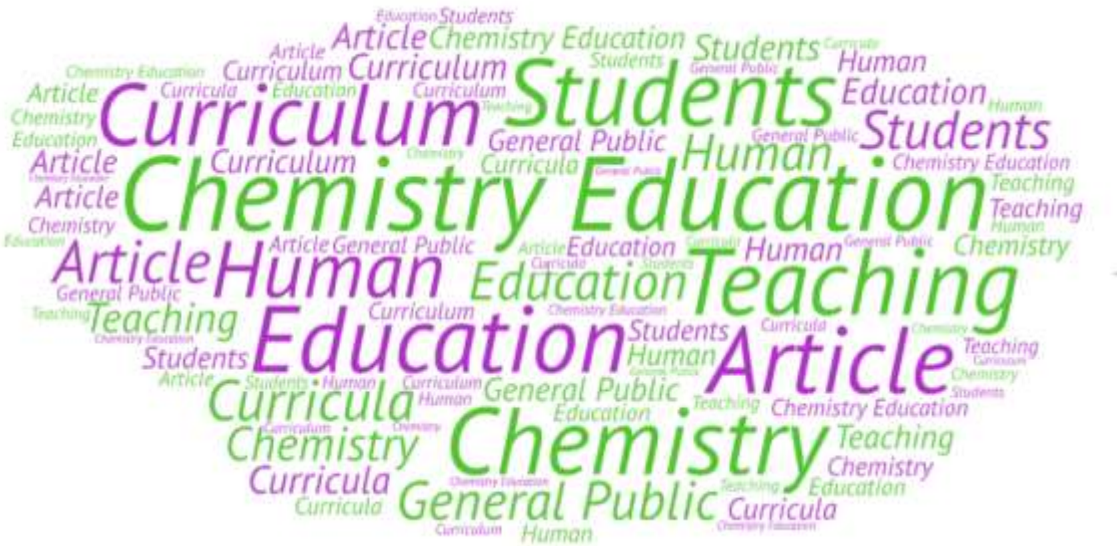
(a)


Upper-Division Undergraduate
E-learning
Review
Higher Education
Sustainable Development
Humans
Interdisciplinary/Multidisciplinary
Priority Journal
Sustainable Development
Chemical Education Research
Review
Humans
Higher Education
Sustainability
Higher Education
Upper-Division Undergraduate
Humans
Chemical Education Research
Priority Journal
Sustainability
E-learning
Humans
Higher Education
Sustainable Development

(b)


Chemical Education
Chemical Analysis
High School/Introductory Chemistry
First-Year Undergraduate/General
Green Chemistry
Chemistry, Clinical
Medical Education
Green Chemistry
Medical Education
Engineering Education
Clinical Chemistry
Chemical Education
Clinical Chemistry
Professional Development
Chemistry, Clinical
Organic Chemistry

(c)



(d)

Fig 4. Word cloud generated by the author keywords for a year of (a) 1980-1989; (b) 1990-1999; (c) 2000-2010 (d) 2011-2020

3. Conclusion

This study has instigated all kinds of scholarly works published from 1980-2020 on chemistry education. The study reports the previous studies' trends using selected bibliometric indicators as gained from the Scopus database. Consequently, these review analyses can help in predicting future research on chemistry education.

4. Co-Author Contribution

The authors affirmed that there is no conflict of interest in this article. Author 1 prepared the literature review and overlooked the write-up of the whole article. Author 2 carried out the analysis and interpretation of the results.

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