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Review article

Use of comparative research in the study of chemistry education: A systematic analysis of the literature

Wing-Fu Lai [a,b,*], Melody Fong [c]

[a] School of Food Science and Nutrition, University of Leeds, Leeds LS2 9JT, United Kingdom
[b] School of Education, University of Bristol, Bristol BS8 ITS, United Kingdom
[c] Department of Applied Biology and Chemical Technology, Hong Kong Polytechnic University, Hong Kong Special Administrative Region, China

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ABSTRACT

Comparative research can help identify the similarities of and differences in different contexts, enabling us to recognize more possibilities and strategies of enhancing our understanding of different aspects of education. To review and analyse the current status of using comparative research designs in chemistry education research, a Boolean keyword search in Scopus and Web of Science has been performed to retrieve articles published from January 2016 to February 2023. In total 7682 entries have been retrieved, but less than 0.01 % of them have applied comparative research in addressing issues of chemistry education. Twelve of the retrieved articles have met the inclusion criteria for further analysis. Though comparative research has been found to be used by over 65 % of the analysed articles to study teaching and learning in chemistry education, its application in curriculum development and student development has been demonstrated by some analysed studies. In addition, 75 % of the analysed articles have declared being funded by local and/or national funding sources. This suggests that the importance of comparative research in chemistry education has been recognized at the national level in various countries. It is hoped that the opportunities brought about by comparative research designs as revealed in this article can enhance the varieties and possibilities in chemistry education research in the forthcoming future.

1. Introduction

Chemistry education involves teaching and learning of skills and concepts of chemistry in academic institutions [1–3], ranging from high schools and colleges to polytechnics and universities [4]. Over the years, extensive efforts have been devoted to understanding the learning process and learning efficiency of chemistry students [5–9] and to enhancing the effectiveness of strategies to improve and assess learning outcomes in different scenarios (including classroom lectures, demonstrations, and laboratory activities) [10–12]. For instance, by interviewing college students at a research-intensive public university, an earlier study has discovered the difficulties among students in building mechanistic explanations for energy transfer between objects at different temperatures [13]. More recently, Belenguer-Sapiña and co-workers [14] have also surveyed a group of 351 pre-university students to study the impact of social chemophobic attitudes on their mindsets, and have noted a tendency among pre-university students to reject everything "containing chemicals". Their findings are important to chemistry education, but are based predominately on a specific set of

* Corresponding author. School of Food Science and Nutrition, University of Leeds, Leeds LS2 9JT, United Kingdom.
E-mail address: rori0610@graduate.hku.hk (W.-F. Lai).

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individuals at a specific period. Till now, the use of a comparative research design to gain insights from multiple scenarios in the context of chemistry education is highly scant.

In fact, making comparisons among different units and entities is an activity of reasoning [15–18], and as suggested by Goedegebuure and van Vught (p. 371) [19], is "*one of the crucial aspects of scientific analysis*''. Comparison enables the awareness of the existence of permanent ignorant comparative reasoning [20], and allows for deconstruction of assumptions about the universal nature of any phenomenon [20]. For this, the use of comparative research in studying chemistry education can potentially raise our awareness of more possibilities and strategies of enhancing our understanding of different aspects of chemistry education [21]. The objective of this article is to review and analyse the current status of using comparative research designs in research on chemistry education. It is hoped that, based on the systematic analysis of the literature, not only can the possible roles played by comparative research designs in enhancing chemistry education be revealed, but the opportunities brought about by comparative research designs can also be envisaged for future research on chemistry education.

2. Importance of comparative approaches in chemistry education research

The basic foundation of scientific research is rooted in comparison [22]. Taking the true experimental design as an example, it is on the comparison of equivalent measures made on equivalent subjects, which are randomly assigned into the test group (in which a treatment is present) and the control group (in which the treatment is absent). Through comparison, the effect of the treatment can be determined as it is the only difference among the two groups to explain the difference in the measures. Putting the role played by comparison in scientific research into consideration, it is not difficult to see why, as mentioned by Smith (pg. 214) [23], "*all research*

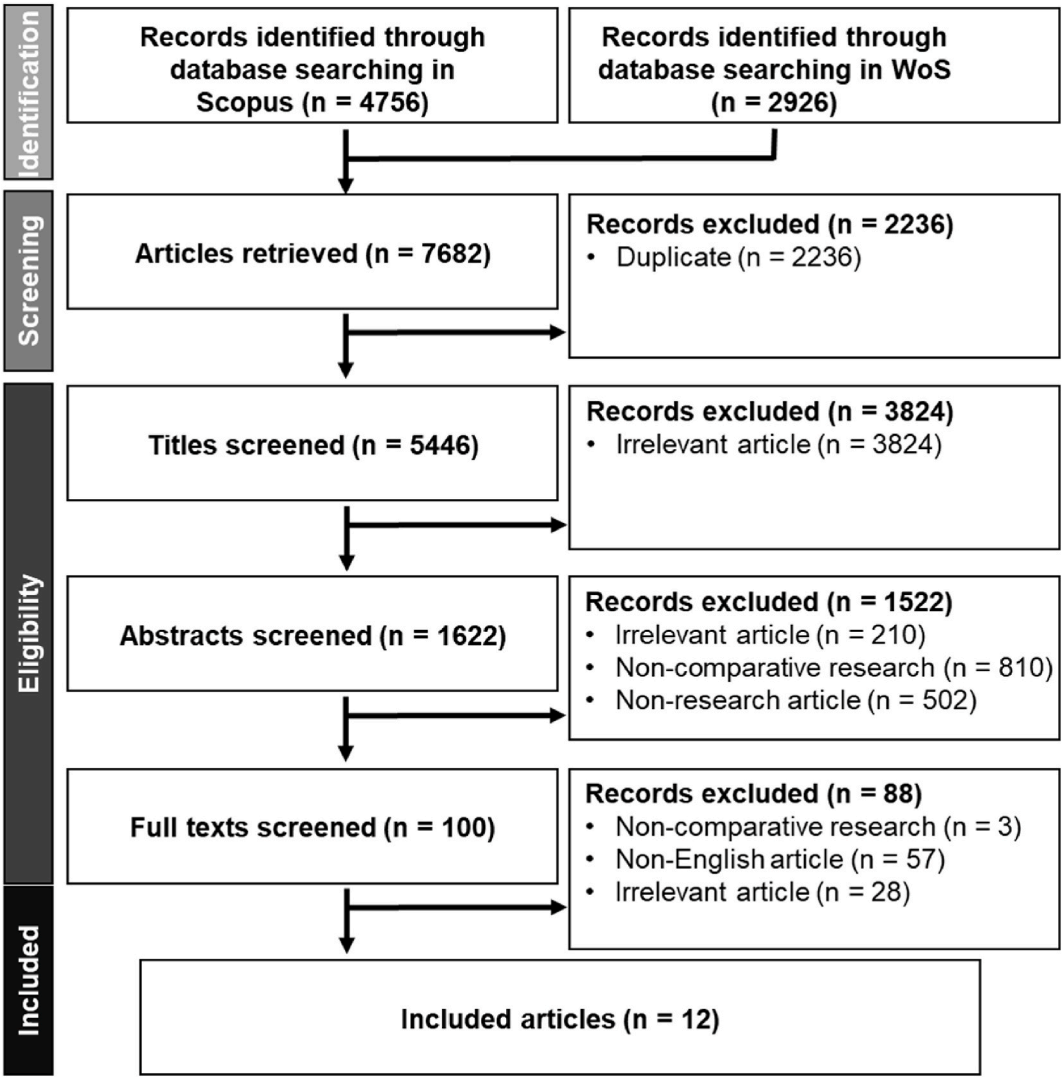

Fig. 1. Flow diagram depicting the process of article selection and evaluation.

that seeks to identify facts is comparative". In this article, a comparative research design is defined, according to the definition given by Paisey and Paisey [24], as "*a method of analysis that focuses on several objects of study in order to identify similarities and differences*" (pg. 181). Its aim is to search for universal patterns, regularities, or general processes from a context-laden environment [25].

Comparative research by itself is not one research approach but is a meta-method in which different approaches of quantitative and qualitative empirical research can be involved [26]. It is typically defined, in the context of educational research, as research in which data (or observations) are attained and compared across geographical, national, and cultural boundaries [26–30], though comparison can also be made within one area (e.g., among different schools within one country) or even one institution (e.g., among different student groups in one school, or among different time periods of the same institution) [26]. Comparative research enables us to face the challenges of globalisation in chemistry education [31,32]. Chemistry education is, in fact, both local and international in nature [3,33]. It is international in a way that people around the world use the same set of technical terms, chemistry laws, chemical symbols, chemical equations, and principles of classification of elements [2,34]. On the other hand, it is local in nature because curricula, students' learning habits, and instructors' teaching practices are largely affected by the local policies and situations (including the economic status, availability of resources, and the extent of industrialization) [35]. With globalisation partially manifested by the persistent change in student demographics, the diversity of students (and also that of teachers) in one school increases continuously, thereby blurring the local dimension while enhancing the international nature of chemistry education [35–37]. By using comparative research, the similarities of and differences in learning styles, curricula and teaching practices in chemistry education among different countries can be identified [35], through which practices to accommodate the needs caused by globalisation of chemistry education can be developed for enhancing the efficiency in teaching and learning.

3. Data collection and analysis

Articles indexed in Web of Science (WoS) and Scopus were found by a Boolean title and abstract search using the following keywords linked by Boolean operators "AND" and "OR": "chem*", "compar*", "teach*", "educat*", and "learn*". The literature from January 2016 to February 2023 was selected for analysis in this paper. 2926 and 4756 entries were retrieved from WoS and Scopus, respectively (Fig. 1). After excluding duplicates of 2236 entries, 5446 entries were obtained. Each of the entries was screened based on the following inclusion criteria.

- The entry was related directly to chemistry education.
- The entry was written in English.
- The entry adopted a comparative research design.
- The entry reported the collection and analysis of primary data.
- The entry used comparison to identify similarities and differences among objects of study to identify general patterns from a context-laden environment, rather than using it to purposely demonstrate the beneficial effects attained by a treatment or intervention administered by the researcher(s) to the human subjects.

All entries that failed to meet any of the above criteria were excluded. A total of 12 studies met all inclusion criteria and were included for further analysis. Article selection was performed independently by both the first author and the second author. Inter-rater reliability was assessed using Cohen's kappa, which was calculated to be 0.84 and considered to have good agreement beyond chance. All disagreements encountered during the article selection process were discussed until consensus was reached. Based on the selected articles, ways of use of comparative research in studies on chemistry education were analysed. Study characteristics (including the study design, setting, country, and funding source) were also extracted for further analysis (Table 1).

4. Results

4.1. Comparative research design in chemistry education research

From 2016 to 2023, there was a steady increase in the number of comparative studies published on the topic of chemistry education, yet the total number of these comparative studies (n = 12) only accounts for less than 0.01 % of all entries retrieved from

Table 1
Categories and items included in the coding scheme of this systematic review.

Coding domain	Items
Source information	Year of publication Institutional affiliation Country of an author's affiliation
Information of data	Source of data Method of data collection Method of data analysis
Setting characteristics	Research design Research objective Participant characteristics

Scopus and WoS over the last several years. Approaches to international comparative education research, as suggested by Bleiklie [38], can be roughly divided into five types: (1) thematic comparison, (2) single-country study, (3) juxtaposition of two or few countries, (4) identification of causal regularities, and (5) analysis on the basis of grand theories. 50 % of the analysed studies, however, belong to the type of "juxtaposition of two or few countries", with the rest of the analysed studies falling into other types of comparative research. This may be because cross-national comparison of research objects is the most traditional and prevalent understanding of comparative research [25].

Authors of the 12 analysed studies come from various countries, including the USA, the Czech Republic, Israel, Italy, Turkey, Finland, Canada, Germany, Jordan, Sweden, South Africa, Iran, Russia, Nigeria, and China (Fig. 2). Among these countries, the USA, Israel, Turkey, Sweden and South Africa appear in at least two of the analysed studies, whereas other countries appear only in one of the 12 analysed articles. 66 % (n = 8) of the analysed studies involve collaborations. Among them, 25 % (n = 2) are performed by researchers from multiple institutions in one country. One of the analysed studies was performed by researchers from various universities (including Florida International University, Grand Valley State University, and Michigan State University) in the USA [39]; whereas another study was conducted by researchers from University of Camerino and Roma Tre University in Italy [40]. In term of the funding sources, 25 % (n = 3) of the analysed articles were self-funded as manifested by the lack of statements declaring the funding source in the published article. The rest of the articles were supported by local and/or national funding sources. Local funding sources reported by the analysed articles come mainly from universities (including Michigan State University, University of Ottawa, and the Charles University Research Centre). National funding sources reported by the analysed articles include the Israel Science Foundation, the Swedish Science Council, the Erna and Victor Hasselblad Research Foundation, and the Natural Science Foundation of Shandong Province of China.

4.2. Areas of use of comparative research

Areas of chemistry education research, in which comparative research methods have been applied, are summarized in Table 2. Over 65 % (n = 8) of the analysed studies applied comparative research to study topics related to teaching and learning in chemistry education (Fig. 3). For instance, one study has compared the Chinese Chemistry Curriculum Standards (CCCS) and the U.S. Next Generation Science Standards (NGSS) to see how chemistry core ideas about substances and processes are represented [41]. Concepts related to various chemical processes (e.g., addition polymerization reaction, redox reaction, and polycondensation reaction) and types of substances (e.g., polymers, oxides, metals, hydrocarbon and its derivatives) have been found to be present in the CCCS but not in the Disciplinary Core Ideas section of the NGSS [41]. This highlights not only the possible variations in the chemistry knowledge of students from different backgrounds but also the resulting challenges imposed to chemistry education when globalisation continues to escalate in education. In addition, organic chemistry students and organic chemistry professors have been compared in their way of thinking about organic chemistry reactions [42], revealing the possibility that students and professors focus on different features [including structural features (e.g., functional groups), chemical properties (e.g., electronegativity and acidity), and reaction-related features (e.g., name of the reaction and types of reaction intermediates)] when they look at reactions. Other areas compared by the analysed studies using the comparative research approach include the concepts of chemical bonding [43], the influences of teacher efficacy and motivation on students' academic performance [44], the conceptual demography of protein synthesis descriptions in textbooks [45], the style and culture of teaching [46], teachers' thoughts about system concept and interdisciplinary approaches in chemistry education [40], and the representation of the concept of Nature of Science (NoS) in textbooks [47].

Apart from studying teaching and learning in chemistry education, 25 % of the analysed studies work on curriculum development. The first study applied comparative research to compare secondary chemistry curricula in seven Arabic countries (including Algeria, Egypt, Jordan, Kuwait, Palestine, Saudi Arabia and Syria) [49]. The second study used comparative research to compare upper-secondary school chemistry curricula in Finland, Turkey and the Czech Republic [50]. The third study compared laboratory curricula to examine the opportunities provided by the curricula for students' engagement in scientific practices [39]. Apart from the aforementioned areas, one study applied comparative research to explore student development. In that study, different groups of participants (including high school students, chemists, chemical engineers, chemistry teachers, and undergraduate chemistry students) have been compared in terms of their perceptions of choosing chemistry as a major and a career [48]. Results of the study showed that choosing chemistry as a major and a profession decreases from high school education to tertiary education [48]. Compared to men, more women tend to choose chemistry at high school and university levels [48]. Further studies to understand the reasons behind may

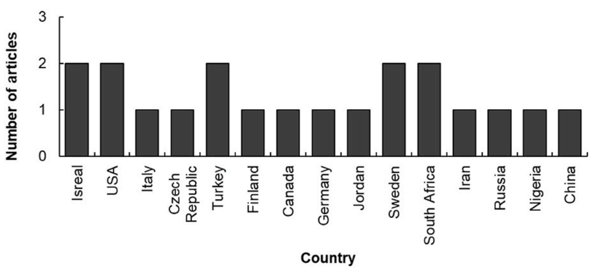

Fig. 2. The number of comparative studies published by each country in the area of chemistry education over the last several years.

Table 2
Areas of chemistry education research in which comparative research methods have been applied.

Area of research	Details of the study	Ref.
Teaching and learning	This study compares the opinions of Italian and international baccalaureate teachers on system concept and interdisciplinary approaches in chemistry education	[40]
	This study conducts a critical comparison of chemistry core ideas between the Chinese Chemistry Curriculum Standards (CCCS) and the U.S. Next Generation Science Standards (NGSS).	[41]
	This study explores how organic chemistry students and organic chemistry professors think about organic chemistry reactions	[42]
	This study examines how Swedish and South African students at the high school and university levels respond to a survey on concepts of chemical bonding.	[43]
	This study investigates the impacts of teacher efficacy and motivation on students' academic achievement in science education in secondary schools and high schools located in Iran and Russia	[44]
	This study investigates the conceptual demography of protein synthesis descriptions in Swedish chemistry and biology textbooks.	[45]
	This study examines factors affecting the study of chemistry in 12 countries. Different parameters have been compared, including the pedagogy and teachers' salaries.	[46]
	This study investigates how the NoS is represented in three Nigerian chemistry textbooks.	[47]
Student development	This study investigates career choice factors and behavioural trends among chemistry students	[48]
Curriculum development	This study compares two laboratory curricula in terms of the extent to which the curricula as a whole provide opportunities for students to engage in scientific practices, and also investigates in which sections of a laboratory activity students most frequently engage specific scientific practices.	[39]
	This study examines the nature of intended secondary chemistry curricula from seven Arabic countries: Algeria, Egypt, Jordan, Kuwait, Palestine, Saudi Arabia and Syria.	[49]
	This study compares, by using the Revised Bloom's Taxonomy, upper-secondary school chemistry curricula in Czechia, Finland, and Turkey.	[50]

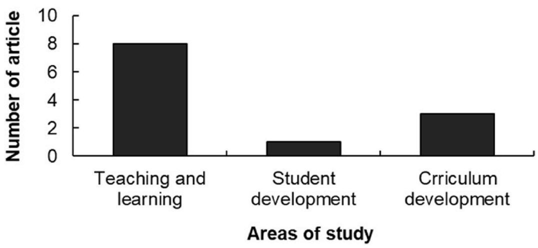

Fig. 3. Areas of study taken up by comparative studies published in the field of chemistry education over the last several years.

help formulate more effective strategies to enhance inclusion and diversity in chemistry disciplines.

4.3. Sources of data in analysed comparative studies

Sources of data adopted by the analysed studies are very diverse (Fig. 4). Around 33 % of the analysed studies used data collected from questionnaires. For instance, Blonder & Mamlok-Naaman surveyed researchers from different countries to examine factors affecting the study of chemistry [46]. By using the Motivation for Academic Performance Scale and the Teacher Self-efficacy Scale, Bal-Taştan and coworkers studied factors influencing students' academic performance [44]. Other examples of comparative studies that used questionnaires for data collection are Nimmermark et al.'s study (which surveyed almost 700 Swedish and South African students to examine their concepts of chemical bonding) [43] and Celestino et al.'s study [which surveyed Italian and International Baccalaureate (IB) teachers to compare their opinions on approaches in chemistry education, discovering that Italian teachers tend to support interdisciplinary teaching more effectively than IB teachers and that IB teachers show a higher tendency to offer study materials (in addition to textbooks) to students than Italian teachers do] [40].

Apart from survey data, some studies used public documents as data for analysis. One example of these documents is curricula. Two

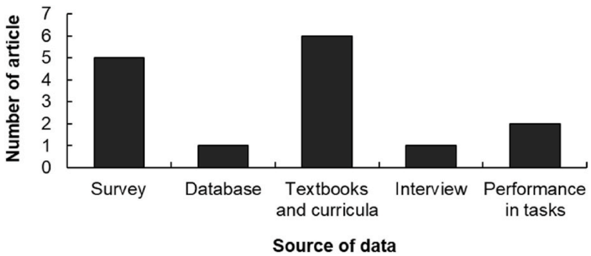

Fig. 4. Sources of data used by comparative studies published in the field of chemistry education over the last several years.

of the 12 analysed studies used curricula directly as the data source. One study coded curricula by using an expanded version of the Three-Dimensional Learning Assessment Protocol (3DLAP) and performed comparison to determine whether those curricula effectively engage students in scientific practices [39]. Another study used the Revised Bloom's Taxonomy (RBT) as the framework to compare and analyse the objectives of upper-secondary school chemistry curricula in Czechia, Finland, and Turkey [50]. Contrary to the Turkish and Finnish ones, the Czech curriculum has been found to more effectively cover the modern trends in chemistry [50]. Such variations in upper-secondary school chemistry curricula among countries may be worth consideration during chemistry education, particularly when the student body is becoming more diverse due to the impact of globalisation in education.

An alternative to curricula is textbooks, which have been used as the data source by around 33 % of the analysed studies. One study compared upper secondary chemistry textbooks with upper secondary biology textbooks, particularly the sections on protein synthesis, to determine the similarities and differences in the conceptual demography of related concepts [45]. Another study collected different chemistry textbooks used in Nigeria [47]. By examining how the NoS concept was represented, it discovered that the textbooks currently used may not be adequate to promote scientific literacy [47]. It advocated the need of revising those textbooks so as to achieve a sustainable understanding of NoS among teachers and students [47]. Apart from the two studies mentioned above, one study conducted qualitative content analysis on the officially approved 10th grade chemistry textbooks used in diverse Arabic countries (including Algeria, Egypt, Jordan, Kuwait, Palestine, Saudi Arabia and Syria) [49]. Textbooks from Algeria, Kuwait and Palestine have been found to mainly adopt a fundamental chemistry and structure-of-the-discipline approach, with the chemistry contents being organised in a way that shows limited connections to modern aspects or practical applications of chemistry [49]. On the other hand, textbooks from Egypt, Syria and Saudi Arabia have been shown to offer a higher degree of contextualisation and to better represent the modern strategy in chemistry teaching [49]. Other than curricula and textbooks, governmental documents and public databases have been used for comparison. The former is exemplified by Avargil et al.'s study [48], which curated data on 545,778 high school graduates from the Israel Central Bureau of Statistics to study the trends of choosing chemistry as a major; whereas the latter is represented by Wan et al.'s work [41], in which a critical comparison of chemistry core ideas between the CCCS and the U.S. NGSS has been conducted.

4.4. *Types of data sources in comparative studies*

Types of data collected at different levels of education for comparative research on chemistry education are shown in Table 3. 75 % (n = 9) and 42 % (n = 5) of the analysed studies were performed in the context of secondary education and tertiary education, respectively. Only one study involved participants from elementary schools. Three out of the 12 analysed studies recruited participants from more than one type of educational institutions. For example, Nimmermark et al.'s survey study on the concepts of chemical bonding was conducted on Swedish and South African students at the secondary-school and university levels [43]. The study reported by Bal-Taştan and co-workers also collected data from secondary schools and high schools in Iran and Russia [44]. More recently, the practice and culture of chemistry teaching at different levels of education (ranging from elementary education to secondary education) in different countries (*viz.*, Estonia, Georgia, the Netherlands, Greece, Israel, Slovakia, Serbia, Portugal, Finland, the Czech Republic, Sweden, and Turkey) were compared by Blonder & Mamlok-Naaman [46], who noted that when chemistry studies are not mandatory at the high-school level, innovative pedagogies (such as context-based and inquiry-based teaching approaches) appear to be more likely adopted on top of the traditional teaching approach (in which chemistry is taught in accordance with the structure of the subject based on basic concepts as delineated in the curriculum) [46]. This provides insights into the subtle relationship between curriculum design and teaching approaches in chemistry education.

Among the 12 analysed articles, 67 % (n = 8) of them adopted only one data source (Table 4). Only four studies used data obtained from multiple sources for comparison. One of these studies was conducted by Avargil and coworkers [48], who not only surveyed various subject groups (*viz.*, chemists, chemical engineers, chemistry teachers, and undergraduate chemistry students) to investigate their retrospective perceptions of choosing a chemistry career but also adopted data curated from the Israel Central Bureau of Statistics for analysis. Another study was carried out by Bal-Taştan and colleagues [44], who not only collected data by using questionnaires but also analysed the grades of students obtained in examination to determine how teacher's efficacy and motivation influence student's academic performance. The third study was performed by Nimmermark et al. [43], who used survey data, textbooks and curricula as

Table 3
Types of data collected at different levels of education for comparative research on chemistry education.

Level of institution	Data for analysis	Ref.
Elementary education	Survey data	[46]
Secondary education	Curricula and related education standards	[41,50]
	Performance in task	[44]
	Survey data	[40,43,44,46,48]
	Data collected by governmental bodies	[48]
	Textbooks	[45,47]
Tertiary education	Survey data	[43,44]
	Curricula and related education standards	[39]
	Textbooks	[49]
	Performance in tasks	[42,44]
	Interviews	[42]

Table 4
Objectives of single-data-source and multi-data-source comparative studies on chemistry education.

Type of study	Research objective	Research instrument	Approach of data analysis	Ref.
Single-data-source study	To characterise scientific practices in general chemistry laboratory curricula	The Three-Dimensional Learning Assessment Protocol	Content analysis	[39]
	To study Italian and IB teachers' opinions on system concept and interdisciplinary approaches in chemistry education	Survey	Statistical analysis	[40]
	To study the representation of chemistry core ideas in science education standards in China and the United States	Curricula	Content analysis	[41]
	To study the conceptual demography in descriptions of protein synthesis in upper secondary chemistry and biology textbooks	Textbooks	Content analysis	[45]
	To determine the factors affecting the study of chemistry in different countries	Survey	Statistical analysis	[46]
	To study the representation of the NoS concept in chemistry textbooks used in Nigeria	Textbooks	Content analysis	[47]
	To study the intended curriculum and its presentation in chemistry textbooks from seven Arabic countries	Textbooks	Content analysis	[49]
	To study the intellectual demands of the intended chemistry curriculum in Czechia, Finland, and Turkey	Curricula	Content analysis	[50]
Multi-data-source study	To investigate how undergraduates, graduate students, and professors organise organic chemistry reactions	Results of a card sort task, and interviews	Content analysis and statistical analysis	[42]
	To study Swedish and South African students' concepts of chemical bonding	Survey, textbooks and curricula	Content analysis and statistical analysis	[43]
	To study the impacts of teacher's efficacy and motivation on student's academic performance in science education in secondary schools and high schools	Survey, and students' performance in an examination	Statistical analysis	[44]
	To study students' trends and perceptions of choosing chemistry as a major and a career	Survey and data collected by the governmental bodies	Statistical analysis	[48]

data sources to study Swedish and South African students' concepts of chemical bonding. The last one was reported by Galloway and co-workers [42], who used a card sort task to assess the performance of participants with a range of knowledge levels and also interviewed participants so as to understand how undergraduates, graduates, and professors organise organic chemistry reactions.

5. Discussions

Chemistry is a discipline that is abstract and multi-representational [51]. This imposes challenges to teaching and learning. The situation is further compounded by the impact of globalisation [4], which forces institutions to enhance the quality of teaching and to ensure that the teaching approach can accommodate the continuous change in student demographics [52,53]. Regarding the fact that comparative research enables the similarities and differences among different objects of research to be identified [54–57], it may provide insights into tackling the impact of globalisation on chemistry education. In this article, the literature from January 2016 to February 2023 have been selected for analysis. Based on the results of our analysis, comparative research has been successfully adopted as a research approach to provide implications for chemistry education. For instance, one of the analysed studies has observed that, in countries where chemistry is a mandatory subject at the high-school level, the subject is usually taught simply based on basic concepts as requested by the curriculum. Yet, when a country no longer puts chemistry as a mandatory subject, more innovative pedagogies from teachers can often be observed [46]. This suggests that, by increasing the autonomy of teachers and by enabling higher flexibility in the curriculum, the quality of teaching might be enhanced. Surely many questions (e.g., what kind of chemistry curricula can be flexible? What tangible benefits such flexible curricula can bring to chemistry education?) still have to be pondered when such findings are translated into practice, but new possibilities for chemistry education have been brought out. Furthermore, by comparing curricula among countries, one study has observed remarkable differences in textbooks and curricula regarding the topics of ionic bonding, bond energetics and the use of the valence-shell electron-pair repulsion (VSEPR) model [43]. It has also reported that the Morse potential energy diagram is commonly adopted as a way to describe bonding in the South African curriculum and in the South African textbooks [43], but such a diagram is neither adopted nor mentioned in the curriculum and textbooks in Sweden [43]. All these imply that the knowledge of, and the training received by, chemistry graduates from different countries may vary. Such a difference should be taken into consideration when chemistry graduates from one country are admitted to a university (or are hired for a chemistry-related position) in another country. More efforts are also needed to be paid when chemistry programmes in one country are accredited or evaluated for equivalence to those in another country.

In fact, through comparison to identify similarities and differences among social entities at different levels, not only can the globalisation of chemistry education be facilitated [21], but insights can also be attained to enhance the quality, practice and efficiency of local chemistry education [58]. Yet, as revealed by the fact that comparative studies on chemistry education only account for less than 0.01 % of all entries retrieved in this article, the use of comparative research to address research questions related to chemistry education is seemingly not sufficiently popular in the mainstream literature. Fortunately, the promising roles potentially played by comparative research in the study of chemistry education appear to start to be recognized not only at the institutional level but also at the national level in various countries. This is demonstrated by our finding that 75 % of the analysed articles were funded by local and/or national funding sources. This reveals that the importance of comparative research is recognized by both internal and external funding agencies, even though the prevalence of the use of comparative research designs in chemistry education research still has much room to be enhanced. Furthermore, as shown by our results, 50 % (n = 6) of the analysed articles were conducted collaboratively by researchers from different countries; whereas 17 % of the articles were carried out among different institutions in one country. This is explained by the fact that comparative research involves comparison to be performed among different scenarios at the institutional, national or global levels [59]. It is possible that the establishment of collaborations can enhance the integration of experience and expertise from researchers from different institutions and/or countries [60], facilitating more in-depth comparison of similarities and variations among different research scenarios and subjects.

For future research, more data sources are suggested to be adopted in one study so that comparison of different research objects can be made in different aspects [21]. This can enhance the deepness and comprehensiveness of future comparative research on chemistry education. As shown by our results, most of the analysed studies have adopted only one source of data for comparison. If more efforts can be paid to involve data obtained from multiple sources, it is expected that a more comprehensive picture of the issue being compared will be attained [61]. This will be able to provide more in-depth understanding and recognition of the similarities and differences among various objects of study. Here it is worth noting that, to maximize the inclusiveness of our literature search for our analysis, we have tried to avoid missing any relevant article by using broad keywords. Despite this, some articles that have not been indexed in Scopus and WoS might still have been ignored. Furthermore, because of our limited capacity to understand non-English languages, we have only analysed English articles. Nevertheless, because most of the influential and mainstream journals are in English, results of this systematic review should be able to reflect the current status of comparative research in the study of chemistry education.

6. Concluding remarks

Comparative research has been employed in the study of chemistry education to examine a variety of topics relevant to teaching and learning, student growth, and curriculum development. Not only can it aid in understanding the nature and status of education in various nations and regions, but it can also offer insights into strategies to address the globalisation of chemistry education. Comparative research is, therefore, expected to become more and more important in the study of chemistry education. Based on the results of our analysis, comparative research on chemistry education is a field far from maturity. Extensive efforts are needed to continue to exploit the roles potentially played by comparative research in the study of chemistry education. In this article, we have analysed some features (including the topic of the study, the funding body, and the data source) of comparative studies on chemistry education, but many questions (e.g., how does the difference in funding sources affect the way comparative studies are conducted? What are the similarities and differences between the issues in chemistry education and in other disciplines of education?) still require further efforts for elucidation. Despite this, comparative research has been gaining increasing attention due to its irreplaceable function in providing insights through comparison [21,61]. With its growing popularity in educational research [62,63], its impact on chemistry education is anticipated to increase continuously in the forthcoming decades.

Data availability statement

Data included in article/supp. Material/referenced in article.

CRediT authorship contribution statement

Wing-Fu Lai: Writing - review & editing, Writing - original draft, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Melody Fong:** Data curation.

Declaration of competing interest

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

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