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Review

Experimental Work in Science Education from Green Chemistry Perspectives: A Systematic Literature Review Using PRISMA

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Abstract: Experimental work is an important component of science subjects at all educational levels. The implication of green chemistry ideas indicated the need for optimization of traditional experimental work by implementing green chemistry principles to promote sustainable development. The aim of the study is to present findings from a systematic literature review on the use of experimental work in science education from green chemistry perspectives in the literature from 1995 to 2020. Thus, three electronic databases were reviewed following the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines. The literature search identified a total of 1199 papers from Web of Science (N = 419), Scopus (N = 578), and Education Resources Information Center (ERIC) (N = 202). After applying inclusion/exclusion criteria, 263 papers were obtained and then analyzed in further detail. The findings highlighted trends in the integration of green chemistry principles into experimental work from primary to tertiary education levels and identified a literature gap, as well as the challenges and the possibilities for future development. The review outlined various opportunities for active learning within experimental work from green chemistry perspectives using a range of methods, with a particular focus on practical, hands-on, and laboratory activities.

Keywords: experimental work; green chemistry; practical work; PRISMA; science education

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1. Introduction

Never have so many students been absent from school simultaneously as during 2020 as a result of the COVID-19 pandemic [1]. Therefore, it is even more important to advocate for higher quality education and pursue the fourth Sustainable Development Goal (SDG) from the 2030 Agenda framework [2,3] to ensure inclusive, equitable, and quality education, and promote lifelong learning opportunities for all [4,5].

Attempts to advance sustainable thinking in practice by focusing on engaging networks of chemists and stakeholders to develop Education for Sustainable Development (ESD) in many institutions go beyond COVID -19 pandemic [6–8]. In 1998, Anastas and Warner published Green Chemistry: Theory and Practice, in which they presented 12 Principles of Green Chemistry that describe what constitutes a greener chemical process, or product [9]: Prevention; Atom Economy; Less Hazardous Chemical Syntheses; Designing Safer Chemicals; Safer Solvents and Auxiliaries; Design for Energy Efficiency; Use of Renewable Feedstocks; Reduce Derivatives; Catalysis; Design for Degradation; Real-Time Analysis for Pollution Prevention and Inherently Safer Chemistry for Accident Prevention.

The American Chemical Society sees green chemistry as a field that is "open to innovation, new ideas, and revolutionary advances" [10]. The growing trend toward green chemistry has also had a significant impact on chemistry education [11,12]. The integration of sustainability and green chemistry in the education of future chemists and chemical engineers has been recognized as crucial to secure students a good position in the future job market and in their social roles [13–17]. This trend continued during the COVID-19 pandemic [18,19]. However, green chemistry topics have rarely been covered at the primary [20,21] and secondary [22,23] education levels to date [24].

In terms of the terminology used, the authors point out that there is no such thing as "green" or "sustainable" in an absolute sense and that the pursuit of greener or more sustainable products, services, and approaches is a collective, i.e., a normative, construct. Therefore, should we refer to green chemistry as "greener chemistry" or "chemistry for greener products," circular chemistry as "chemistry in the context of a circular economy," and sustainable chemistry as "chemistry for sustainability" [25]? Zuin et al. claim that education is at the heart of understanding and projecting the future transformation of these normative parts of "chemistry," which is a fundamental key to understanding their socio-historical constitution [26].

As shown in the review by Andraos and Dicks [12], various approaches have been developed to introduce students to green chemistry ideas, e.g., the introduction of green chemistry into the curriculum [14,27,28], textbooks, and other learning materials [29–31], lectures and full courses in green chemistry [32–34], various types of metrics for determining the "greenness" of a chemical reaction [35–38], and experimental work related to the green chemistry principles [39–42].

In order to support further development of green chemistry education, which has been recognized as one of the important topics in ESD [11,15,17], and thereby to focus especially on the trends and the needs related to specific educational methods, this article focuses primarily on a review of laboratory experimental work related to green chemistry to support quality of education, as experimental activities are recognized to have a distinctive and central role in the science curriculum. In addition, numerous benefits have been reported from engaging students in science laboratory activities [43–49].

Hofstein [45] observed that the following important reasons are still relevant 30 years after his review on the use of laboratory work in chemistry education: (1) "School laboratory activities have special potential as media for learning that can promote important science learning outcomes for students; (2) Teachers need knowledge, skills and resources that enable them to teach effectively in practical learning environments. They need to be able to provide opportunities for students to interact both intellectually and physically by conducting hands-on investigations and minds-on reflection; (3) Student perceptions and behaviors in the science laboratory are greatly influenced by teacher expectations and assessment practices, as well as the orientation of the associated laboratory guide, worksheets, and electronic media; (4) Teachers need ways to find out what their students are thinking and learning in the science laboratory and classroom".

Experimental work is essential for the teaching and learning of chemistry because it combines several activities with different objectives. Therefore, the planning of its implementation must be guided by the effectiveness of the planned performance in achieving the learning objectives [50]. The important purpose of experimental work in science education is to help students make connections between real objects, materials, and events and the abstract world of thoughts and ideas [47]. Tiberghien [51] believes that experimental work can help students develop an understanding of the connection between the two levels of knowledge: the level of objects and observations and the level of ideas. Abrahams and Millar [47] found that experimental work is also crucial for students to learn how to use laboratory equipment, but educators should pay careful attention to improving its efficiency in facilitating students' learning based on the data collected for the development of scientific ideas.

Previous review articles have reported on various aspects of the use of green chemistry in education, e.g., laboratory work in tertiary education [12,27,52–59], often only in a specific field of chemistry [52,56,57], and the integration of selected green chemistry principles into laboratory work in tertiary education [53,56,57]. The present paper aims to review experimental work from green chemistry perspectives more holistically by involving all fields of chemistry, all educational levels, and 12 Principles of Green Chemistry in a 25-year long period. To examine the possibilities of experimental work in green chemistry education, the following research questions were established:

RQ1: What are the characteristics (year of publication, journal of publication, ISSN [e-ISSN], type of paper, field of chemistry) of the reviewed papers published from 1995 to 2020?
RQ2: What are the main purposes of the reviewed papers?
RQ3: Which learning type is predominant in the reviewed papers?
RQ4: What education level do the reviewed papers focus on?
RQ5: Which green chemistry principles are addressed in the reviewed papers?

2. Materials and Methods

A systematic literature review method was used to address the objectives of the study and provide a comprehensive insight into the possibilities of experimental work in green chemistry education. To conduct a systematic literature review, we followed the updated Preferred Reporting Items for Systematic Reviews (PRISMA) 2020 guidelines [60], which focus on several aspects to ensure transparent, replicable, and scientifically adequate systematic reviews. Accordingly, a protocol was established to define the research questions and describe the chosen information sources, search strategy, selection criteria, data extraction, and analysis.

2.1. Information Sources and Search Strategy

The systematic literature review performed in this study comprised an advanced search of published articles between the years 1995 and 2020 in three electronic databases: Web of Science (WoS) Core Collection, Scopus, and Education Resources Information Center (ERIC). The selection of these three databases was based on their internationally recognized impact indices containing peer-reviewed scientific and scholarly literature published worldwide and across different scientific fields and disciplines [61,62].

The search strategy was based on the use of core concepts regarding the subject of the study (green chemistry, teach *, learn *, educ *, experiment *, practice *, laborator *) and research questions utilizing the Boolean operators (AND, OR) with simple operators using parentheses in the search string [63]. After testing and quickly reviewing the syntax required by each database, a search string was generated (Table 1).

Table 1. Information source and search strategy.

Information Source	Search String and Parameters
WoS Core Collection	(TI = (green chemistry) OR AB = (green chemistry) OR AK = (green chemistry)) AND (TI = (experiment * OR practice * OR laborator *) OR AB = (experiment * OR practice * OR laborator *) OR AK = (experiment * OR practice * OR laborator *)) AND (TI = (educ * OR teach * OR learn *) OR AB = (educ * OR teach * OR learn *) OR AK = (educ * OR teach * OR learn *)) Timespan: 1995-01-02–2021-01-02 Document type: Article, Review Article Language: English
Scopus	(TITLE (green AND chemistry) OR ABS (green AND chemistry) OR KEY (green AND chemistry)) AND (TITLE (experiment * OR practice * OR laborator *) OR ABS (experiment * OR practice * OR laborator *) OR KEY (experiment * OR practice * OR laborator *)) AND (TITLE (educ * OR teach * OR learn *) OR ABS (educ * OR teach * OR learn *) OR KEY (educ * OR teach * OR learn *)) AND (PUBYEAR > 1994) AND (EXCLUDE (PUBYEAR, 2021)) Document type: Article, Review Language: English
ERIC	((ab ((green chemistry)) OR ti ((green chemistry)) OR if ((green chemistry))) AND (ab ((educ * OR teach * OR learn *)) OR ti ((educ * OR teach * OR learn *)) OR if ((educ * OR teach * OR learn *))) AND (ab ((experiment * OR practice * OR laborator *)) OR ti ((experiment * OR practice * OR laborator *)) OR if ((experiment * OR practice * OR laborator *)))) Timespan: 1995-01-02–2021-01-02 Document type: Journal Articles Language: English

Note: The asterisk (*) sign was used as a truncation operator. Asterisks were appended to the stem of a word, which allowed searching for all words containing that stem or the letters preceding the asterisk.

Only peer-reviewed articles were included in the study to increase its credibility and integrity. In the continuation of the search, additional parameters (document type: articles, review articles; language: English) to refine the search results were used in each database based on the inclusion and exclusion criteria described in Section 2.2. To offer as broad an overview as possible, specific journals in the search strategy phase were not chosen [64]. The final search in all databases was performed in August 2021.

2.2. Inclusion and Exclusion Criteria

With the intention to select and include only relevant studies for our research topic identified from the databases, specific inclusion and exclusion criteria were defined.

2.2.1. Inclusion Criteria

IC1: Journal articles.
IC2: The study is written in English.
IC3: The study is peer-reviewed.
IC4: The study is not listed in another database.
IC5: The study was conducted in an educational environment (primary, secondary, or tertiary education).
IC6: The study is related to science subjects.
IC7: The full text of the study is available.
IC8: The study includes reviews, research, or descriptions of green chemistry practices.
IC9: The study addresses experimental work in green chemistry education.

2.2.2. Exclusion Criteria

EX1: Proceedings of congresses, conference papers, books, book chapters, and other nonpeer-reviewed publications.
EX2: The study is not written in English.
EX3: The study is not peer-reviewed.
EX4: The study is listed in another database.
EX5: The study was not conducted in an educational environment (primary, secondary, or tertiary education).
EX6: The study is not related to science subjects.
EX7: The full text of the study is not available.
EX8: The study only includes opinions about green chemistry practices.
EX9: The study does not address experimental work in green chemistry education or it mentions it just briefly.

2.3. Data Collection and Analysis

The systematic literature review was carried out in five phases following the PRISMA 2020 guidelines [65]. The first phase consisted of an initial search of the literature included in the WoS (n = 419), Scopus (n = 578), and ERIC (n = 202) electronic databases. Based on the inclusion (**IC1, IC2, IC3**) and exclusion (**EX1, EX2, EX3**) criteria, a total of 313 papers (305 chosen by database automation tools and eight by a human) were excluded as ineligible regarding the type of paper, language, and peer-review criteria. Regarding the inclusion and exclusion criteria (**IC4, EX4**) 409 duplicate papers were excluded using Microsoft Excel software. In the second phase, the inclusion (**IC5, IC6**) and exclusion (**EX5, EX6**) criteria were applied by reviewing the title and abstract of 476 papers. In case of insufficient or vague abstracts, the entire paper was browsed. Six papers that were not available in full text were excluded for further analysis (**IC7, EX7**). In the fourth phase, a total of 372 papers were carefully screened for eligibility by applying inclusion (**IC8, IC9**) and exclusion (**EX8, EX9**) criteria. In the fifth phase, the full text of the remaining 263 papers were reviewed thoroughly for relevance to our criteria and research questions. The described process is summarized in a PRISMA flow diagram (Figure 1).

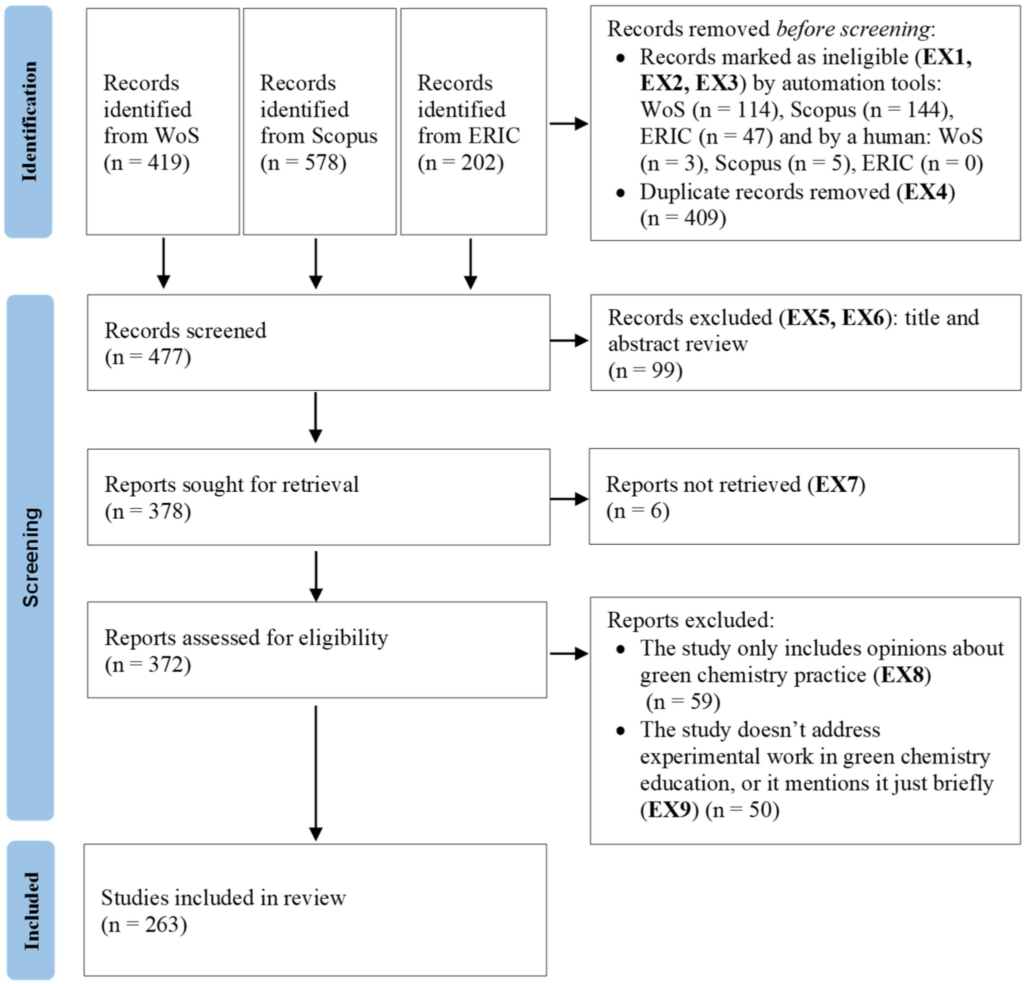

Figure 1. PRISMA 2020 flow diagram [60].

The corresponding table for all included papers (*n* = 263) in the systematic literature review can be found in the Appendix A (Table A1). The coding number of the paper and the electronic database from which it was extracted (all papers from Scopus [and duplicates in WoS and ERIC] = S; all papers from WoS [and duplicates in ERIC] = W; all papers from ERIC = E) are also provided and follow the codification [66] used to identify specific papers to discuss the results of the analysis.

The following data were extracted from each paper: (1) field of chemistry, (2) type of paper, (3) purpose of the paper, (4) learning type, (5) educational level/target groups, and (6) green chemistry content (regarding green chemistry principles).

Two researchers (the authors of this paper) independently performed the systematic literature review following the established protocol using the same inclusion and exclusion criteria and descriptors. The authors compared and confirmed their findings. The degree of agreement on the inclusion of papers was 98%. Disagreements were resolved by discussion and shared consensus.

3. Results

3.1. What Are the Characteristics of the Reviewed Papers Published from 1995 to 2020?

A total of 263 papers met the objectives of the study and the inclusion and exclusion criteria (Figure 1). The first identified paper that focused on experimental work from green chemistry perspectives was published in 2000 in the *Journal of Chemical Education* and addressed "an environmentally benign synthesis of adipic acid" aimed at organic instructors [67]. However, more intense research from green chemistry perspectives began in 2011 and reached a peak in 2019 with 42 papers (duplicates excluded). More than half of all reviewed papers (*n* = 140) were published in the previous five years (2015–2020) (Figure 2).

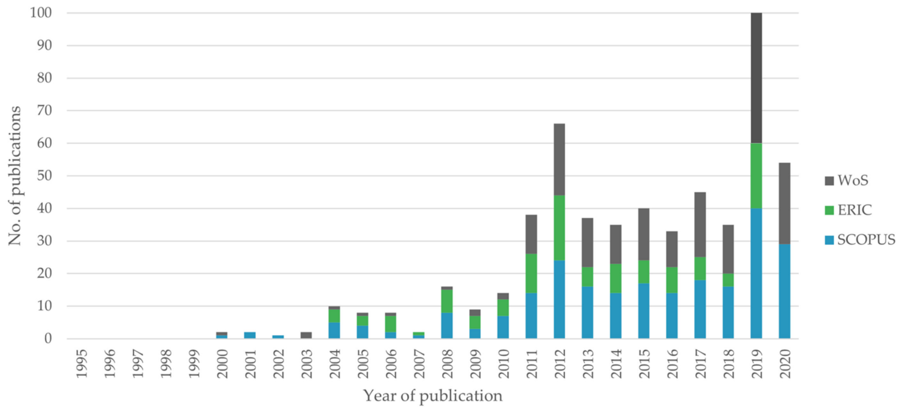

Figure 2. Grouping of publications by year and electronic database (WoS, ERIC, and Scopus) dealing with experimental work from green chemistry perspectives (Note: In Figure 2, the duplicate papers are not excluded.).

Table 2 lists the scientific journals in which papers addressing experimental work from green chemistry perspectives were published between 1995 and 2020. As can be seen from Table 2, the majority of papers (*n* = 200) were published in the *Journal of Chemical Education*. This finding is in agreement with Marques et al. [68], who noted that almost half of the scientific papers on the wider topic of green chemistry education in the WoS were published in the *Journal of Chemical Education*. Both studies suggest that this journal can be recognized as an important source for the dissemination of practices in educational settings in this field at the international level.

The remaining journals that published several articles addressing experimental work from green chemistry perspectives are: *Green Chemistry Letters and Reviews* (*n* = 8), *Physical Sciences Reviews* (*n* = 7), *Chemistry Education Research and Practice* (*n* = 5), *Current Opinion in Green and Sustainable Chemistry* (*n* = 4), *Journal of Science Education* (*n* = 3), *Green Chemistry* (*n* = 3), *ACS Chemical Health and Safety* (*n* = 2), *ACS Symposium Series* (*n* = 2), *Quimica Nova* (*n* = 2), and *Research in Science & Technological Education* (*n* = 2). In a further 25 journals, one paper on this topic was published (Table 2).

In Table 3 the reviewed papers are presented according to the “type of paper,” e.g., literature review, experience report, or evaluation study. Thus, 17 review papers and 41 evaluation studies were identified. However, most of the research papers (*n* = 205) were experience reports that focused on the development and implementation of practical activities related to experimental work from green chemistry perspectives.

From green chemistry perspectives, the experimental work was mostly addressed in relation to organic chemistry (*n* = 150, Table 4). The integration of green chemistry into education was most notable in the context of optimizing organic syntheses, which was an aspect repeatedly highlighted in the literature [12,52]. As can be seen from Table 4, other papers addressed experimental work in general chemistry (*n* = 23), analytical chemistry (*n* = 21), inorganic chemistry (*n* = 15), chemistry (*n* = 12), polymer science (*n* = 10), physical chemistry (*n* = 9), environmental chemistry (*n* = 7), and some papers in other fields of chemistry (*n*=16), which reflects the need for the introduction of green chemistry ideas into various fields of chemistry.

Table 2. Scientific journals with papers published between 1995 and 2020 dealing with experimental work from a green chemistry perspective.

Journal	Publisher	ISSN [e-ISSN]	5-Year IF *	No. of Papers	Paper Code
Journal of Chemical Education	American Chemical Society	0021-9584 (1938-1328)	2.37	200	S1-S7, S9-S13, S15-S23, S25-S36, S38-S42, S44-S47, S49-S51, S55-S58, S60, S61, S64-S66, S68-S74, S76-S82, S84-S86, S88-S93, S101-S108, S110 S114-S123, S125, S127-S135, S137, S139-S143, S145, S146, S148, S152-S154, S156, S158-S167, S170, S171, S173-S183, S185-S196, S198, S200-S204, S206, S208, S211-S214, S216-S226, 1W, 3W, 7W, 10W, 1E-19E
Green Chemistry Letters and Reviews	Taylor and Francis Ltd.	1751-8253 (1751-7192)	3.963	8	S53, S54, S168, S169, S184, 2W, 5W, 6W
Physical Sciences Reviews	De Gruyter	2365-659X (2365-659X)	0.811	7	S14, S24, S48, S109, S136, S144, S230
Chemistry Education Research and Practice	Ioannina University School of Medicine	1109-4028 (1756-1108)	2.57	5	S8, S62, S98, S111, S210
Current Opinion in Green and Sustainable Chemistry	Elsevier BV	2452-2236	5.546	4	S87, S52, S94, S197
Journal of Science Education	Taylor and Francis Ltd.	0950-0693 (1464-5289)	2.302	3	S43, S67, S207
Green chemistry	Royal Society of Chemistry	1463-9262 (1463-9270)	9.905	3	S232, 9W, 11W
ACS Chemical Health and Safety	American Chemical Society	1871-5532 (1878-0504)	1.196	2	S138, S199
ACS Symposium Series	American Chemical Society	0097-6156 (1947-5918)	0.474	2	S227, S228
Quimica Nova	Sociedade Brasileira de Quimica	0100-4042 (1678-7064)	0.739	2	S59, S155
Research in Science & Technological Education	Taylor and Francis Ltd.	0263-5143 (1470-1138)	1.764	2	S75, S172
Other journals with one identified paper each (listed alphabetically): *ACS applied materials & interfaces, ACS Omega, ACS Sustainable Chemistry and Engineering, Analytical and Bioanalytical Chemistry, Applied Materials Today, Asia-Pacific Education Researcher, Asia-Pacific Forum on Science Learning and Teaching, Chemistry-Didactics-Ecology-Metrology, ChemSusChem, Chromatographia, Chimica Oggi, Educacion Quimica, Environmental Education Research, Indian Journal of Pharmaceutical Education and Research, International Journal of Sustainability in Higher Education, Journal of Science Teacher Education, Jurnal Pendidikan IPA Indonesia, Macedonian Journal of Chemistry and Chemical Engineering, Multidisciplinary Journal for Education Social And Technological Sciences, Polish Journal of Environmental Studies, Sustainability, Sustainable Chemistry and Pharmacy, TrAC—Trends in Analytical Chemistry, Waste Management, World Transactions on Engineering and Technology Education.*				25 (one in each of the listed journals)	S149, S151, S112, S37, S150, S96, S95, 4W, S157, S209, S229, S205, S99, S233, S100, S97, S126, S147, 8W, S215, S124, S83, S113, S63, S231
Total				263	

* Note: According to the data published on the Academic Accelerator website [69].

Table 3. Papers dealing with experimental work from green chemistry perspectives published between 1995 and 2020 according to the type of paper.

Type of Paper	Frequency	Paper Code
Experience report	205	S1-S3, S5-S7, S9, S11, S14-S23, S26-S35, S37-S48, S49-S51, S55-S57, S59, S61-S74, S78-S86, S88-S92, S102-S108, S110, S112-S116, S119, S121-S125, S127-S132, S134-S136, S138, S141-S143, S147, S149, S151-S156, S158-S166, S170, S171, S173-S175, S177-S182, S184, S187-S196, S198-S202, S204-S209, S211-S214, S216-S233, 1W-4W, 6W, 9W, 10W, 11W, 1E-5E, 7E-19E
Evaluation study	41	S4, S10, S13, S24, S25, S36, S58, S60, S75-S77, S93-S101, S117, S118, S120, S126, S133, S139, S140, S145, S146, S148, S167-S169, S172, S176, S183, S203, S210, 7W, 8W, 6E
Review	17	S8, S12, S52-S54, S87, S109, S111, S137, S144, S150, S157, S185, S186, S197, S215, 5W
Total	263	

Table 4. Papers dealing with experimental work from green chemistry perspectives published between 1995 and 2020 according to the field of chemistry.

Field of Chemistry	Frequency *	Paper Code
Organic chemistry	150	S1, S2, S4, S5, S7, S12, S16-S18, S20, S21, S23, S25, S27, S28, S33, S36, S38-S40, S42, S44, S47, S49, S50, S52-S56, S59-S62, S64, S67-S74, S78-S82, S84, S85, S90-S93, S102-S104, S108, S110, S114-S117, S120-S123, S125, S128, S131-S134, S136, S137, S139, S141, S142, S144-S147, S151-S157, S162, S163, S165, S166, S170, S174-S176, S178, S182, S183, S185-S187, S190, S191, S193-S195, S198, S201, S203-S207, S210, S212-S214, S217, S219, S222-S224, S227-S232, 1W-6W, 9W, 10W, 2E, 3E, 5E, 6E, 8E-12E, 14E, 16E, 17E
General chemistry	23	S6, S10, S12, S14, S29, S31, S32, S48, S101, S105, S127, S152, S156, S160, S164, S172, S173, S192, S198, S216, S220, S226, 18E
Analytical chemistry	21	S3, S30, S36, S37, S58, S66, S75, S111, S113, S118, S151, S157, S160, S164, S187, S202, S212, S221, S223, S209, 7E
Inorganic chemistry	15	S9, S17, S36, S41, S46, S57, S65, S70, S76, S90, S149, S189, S196, S220, 7W
Chemistry	12	S13, S94-S100, S109, S126, S150, S211
Polymer science	10	S35, S36, S88, S106, S107, S129, S140, S177, S200, S221
Physical chemistry	9	S36, S45, S159, S161, S172, S180, S206, S212, 13E
Environmental chemistry	7	S11, S51, S63, S112, S143, S148, 19E
Materials Science	3	S89, S135, S179
Biochemistry	2	S188, S218
Interdisciplinary	2	S26, S208
Industrial chemistry	1	S34
Organic catalysis	1	S158
Electrochemistry	1	S124
Chemical technology	1	S225
Other	5	S15, S19, S119, S130, S233
Not defined	23	S8, S22, S24, S43, S77, S83, S86, S87, S138, S167, S168, S169, S171, S181, S184, S197, S199, S215, 8W, 11W, 1E, 4E, 15E

Note: * Some reviewed papers describe or indicate implementation of experimental work from green chemistry perspectives for more than one field of chemistry.

3.2. What Are the Main Purposes of the Reviewed Papers?

The analysis of the presented systematic review attempts to provide an overview of the main purposes for integrating green chemistry into experimental work addressed in the papers (Table 5). The results show that most of the reviewed papers focus on the integration of green chemistry into traditional chemistry teaching (n = 228), e.g., with the optimization of experimental work in terms of green chemistry principles [70–77]. In a further 30 reviewed papers, the integration of green chemistry into the curriculum was mentioned, some also in the context of the main benefit of improving chemical safety. In addition, 31 papers addressed a strong synergy between chemical safety and green chemistry goals [27,78–80]. Some papers (n = 27) focus on integrating green chemistry metrics into traditional chemistry teaching [81], while others also compare traditional experimental work to experimental work optimized with green chemistry principles [82–84]. This is particularly important given the debate in the literature about what is or is not green chemistry [52,68]. Researchers also indicated the scope of their papers in promoting green chemistry education (n = 24) and also by solving socio-environmental problems from green chemistry perspectives (n = 21) [22,85,86]. The opportunity to promote systems thinking [87] (n = 17) and life-cycle thinking [88] (n = 16) within green chemistry education was also highlighted to provide innovative solutions to current and future sustainability challenges. Other indicated purposes of the reviewed papers include developing green and sustainable products (n = 17), identifying green chemistry approaches in green chemistry education (n = 15), improving and creating teaching materials (n = 9), and developing green skills (n = 9). Some studies (n = 6) also presented the use of innovative didactic tools in teaching and learning about green chemistry [89,90].

Table 5. Indicated purposes of papers dealing with experimental work from green chemistry perspectives published between 1995 and 2020.

Purpose of Papers	Frequency *	Paper Code
Integrating GC into traditional chemistry teaching	228	S1-S12, S14-S20, S23-S25, S27-S42, S44-S51, S53-S62, S65, S67-S70, S72-S75, S77-S97, S99-S142, S144-S149, S151-S166, S170-S199, S201-S207, S209, S213, S217, S219, S224, S226, S228-S233, 1W-11W, 1E-5E, 7E-16E, 19E
Fostering a culture of safety	31	S1, S12, S35, S48, S76, S91, S109, S112, S118, S119, S126, S127, S131, S136-S138, S140, S141, S144, S157, S162, S164, S165, S185, S195, S197, S198, S199, S211, 8W, 16E
Integrating GC into curriculum	30	S10, S12, S41, S48, S51, S56, S76, S77, S83, S87, S109, S113, S119, S120, S124, S126, S134, S137, S144, S157, S160, S165, S167, S171, S202, S223, S230, 6W, 8W, 7E
Integrating GC metrics into traditional chemistry teaching	27	S5, S38, S46, S52, S64, S66, S71, S83, S109, S115, S139, S145, S146, S167-S169, S185, S193, S197, S203, S226, 2W, 7W, 1E, 4E, 6E, 17E
Promoting green chemistry education	24	S2, S13, S14, S26, S27, S37, S43, S47, S54, S57, S66, S97, S99, S109, S143, S151, S152, S176, S186, S199, S203, S200, S233, W7
Socio-scientific approach	21	S4, S24, S26, S96, S107, S143, S149, S157, S161, S164, S165, S171-S173, S176, S180, S197, S199, S200, S204, S226
Development of systems thinking	17	S10, S12, S26, S36, S45, S51, S87, S101, S115, S116, S129, S139, S143, S156, S179, S204, S226
Development of green and sustainable products	17	S2, S21, S22, S24, S28, S35, S63, S106, S107, S130, S150, S153, S158, S177, S200, S212, S227
Development of life-cycle thinking	16	S2, S10, S20, S36, S57, S62, S76, S129, S149, S179, S185, S216, S225, S226, 2W, 4E
Identifying GC approaches for GC education	15	S8, S13, S26, S51, S74, S75, S98, S109, S113, S126, S157, S197, S208, S210, S222
Improvement and creation of teaching material	9	S37, S67, S113, S135, S197, S218, S220, S221, S223
Development of green skills	9	S1, S2, S24, S133, S141, S146, S161, S214, 19E
Use of innovative didactic tools	6	S34, S62, S74, S87, S195, S197
Promoting chemistry education	1	S27
Other (informative)	1	S215

* Note: Some reviewed papers describe or indicate the implementation of experimental work from green chemistry perspectives for more than one field of chemistry.

3.3. Which Learning Type Is Predominant in the Reviewed Papers?

The learning type category (Table 6) sought to review the learning types that were formulated and/or discussed in each paper. In this sense, we used Laurillard's concept of learning types derived from her "conversational framework" model, i.e., acquisition, inquiry, practice, discussion, collaboration, and production [91]. As can be seen from Table 6, learning with practice predominates (n = 158) in the reviewed papers and most papers describe a laboratory setting in organic chemistry.

Table 6. Papers dealing with experimental work from green chemistry perspectives published between 1995 and 2020 according to the predominant learning type.

Learning Type	Frequency *	Paper Code
Learning through practice	158	S2-S5, S7, S9, S13-S15, S33, S35, S37-S42, S44, S45, S49, S50, S58, S63, S65, S68, S71, S74, S77, S79, S85, S89, S91, S92, S95-S97, S102, S104, S105, S112, S114, S115, S117, S118, S122, S123, S125-S127, S129, S131, S132, S134-S137, S139-S142, S144, S146, S149-S156, S158, S159, S161-S165, S167-S172, S174-S181, S183-S196, S199-S207, S209, S211, S213, S214, S216-S225, S227-S229, S232, S233, 1W-4W, 7W-9W, 11W, 1E-9E, 11E-15E, 17E, 18E, 19E
Learning through inquiry	86	S1, S6, S10, S11, S16-S32, S34, S36, S46, S47, S52, S55-S57, S59-S62, S64, S66, S67, S69, S70, S72, S73, S76, S78, S80-S84, S88, S90, S93, S94, S101, S103, S106-S108, S110, S116, S119-S121, S124, S128, S130, S133, S143, S145, S147, S148, S160, S166, S173, S178, S182, S183, S198, S208, S212, S226, S230, S231, 5W, 6W, 10W, 10E, 16E
Learning through collaboration	15	S2, S6, S26, S31, S34, S62, S69, S73, S74, S146, S176, S178, S183, S195, S231
Learning through discussion	13	S1, S13, S15, S20, S22, S26, S31, S41, S46, S115, S141, S172, S195
Learning through acquisition	2	S86, S163
Integrated teaching	1	S210
Other	2	S8, S43
Not defined/Not relevant	16	S12, S48, S51, S53, S54, S87, S98, S99, S100, S109, S111, S113, S138, S157, S197, S215

* Note: Some reviewed papers refer to more than one learning type.

With the intention to support students' development of high-order thinking skills in the laboratory, several papers identified the use of inquiry-based learning (n = 86). Learning through collaboration, sometimes related to problem- and project-based learning was mentioned in some papers (n = 15). Similarly, learning through discussion was highlighted (n = 13). A minority of papers (n = 2) were categorized in the framework of acquisition, e.g., experimental work optimized from green chemistry perspectives that can be performed as a demonstration. From some articles (n = 16), it was not possible to identify the learning type because they were, e.g., review papers or general descriptions of ideas for how green chemistry could be integrated into experimental work.

3.4. What Education Levels Do the Reviewed Papers Focus on?

According to the data presented in Table 7, most studies refer to tertiary education students in nonpedagogical study programs (n = 224). These students are typically older than 18 years. Fewer papers refer to secondary education (n = 33) with students aged 12–18 years and primary education (n = 2) with students aged 6–11 years. Some papers (n = 16) broadened their scope by proposing targeting students at two education levels (mainly tertiary and secondary) and several papers (n = 8) did not mention the target groups or the education level, which could indicate the less evident scope of these articles for the integration of green chemistry perspectives in education [68].

As can be seen from Table 7, only 12 papers targeted the teacher population. Pre-service teachers (tertiary education—pedagogical studies) were addressed in nine articles. Some of these articles described examples of the integration of green chemistry experimental work [39,83,92–97], whereas others evaluated activities for integration of green chemistry into experimental work [95,97,98]. The incorporation of green chemistry experiments into the education of pre-service teachers was recognized as a way to promote the development of students' pro-environmental attitudes, values, knowledge, and motivation [39,95–97]. On the other hand, in-service teachers were specifically mentioned in only three papers. In this regard, in-service university teachers were supported with materials related to optimization of the use of solvents (green chemistry principle 5) in organic experiments in courses for undergraduate students [56,57] and only one article addressed [99] in-service teacher training focused on green chemistry experiments for secondary school teachers.

Table 7. Papers dealing with experimental work from green chemistry perspectives published between 1995 and 2020 according to the education level they addressed.

Education Level	Frequency *	Paper Code
Tertiary education—nonpedagogical studies (19-years old)	224	S1-S12, S14-S21, S23-S25, S29, S30, S32-S36, S38-S42, S44-S49, S51, S52, S55-S59, S61, S64, S65, S67-S82, S84, S85, S88-S93, S101-S105, S108, S110, S112-S125, S127-S139, S141, S142, S144-S146, S148-S167, S169, S170, S172-S183, S185-S188, S190-S196, S198, S201-S209, S211-S214, S216-S219, S221-S226, S228, S229, S231-S233 1W-3W, 5W, 6W, 8W-10W, 1E-5E, 7E-14E, 16E, 17E, 19E
Secondary education (12–18 years old)	33	S13, S22, S28, S31, S32, S50, S60, S62, S83, S86, S95, S96, S106, S107, S111, S114, S126, S140, S143, S147, S167, S184, S189, S198, S199, S200, S210, S220, S230, 4W, 6E, 15E, 18E
Tertiary education—pedagogical studies (19-years old)	9	S26, S27, S50, S66, S97, S98, S99, S100, 7W
Primary education (6–11 years old)	2	S43, S86
In-service teacher education	3	S53, S54, S94
All levels	1	S87
Not defined	8	S37, S63, S109, S168, S171, S197, S227, 11W

* Note: Some reviewed papers address more than one education level and target groups.

3.5. Which Green Chemistry Principles Are Addressed in the Reviewed Papers?

A large number of papers included in the systematic literature review refer directly or indirectly to the 12 Principles of Green Chemistry, which is not surprising because the principles are a foundation of green chemistry. The results of the analysis are presented in Table 8, where the most frequently addressed green chemistry principles are listed first, while the least frequently addressed principles are shown at the bottom of the table.

Table 8 shows that a considerable number of papers deal with the substitution of solvents and other auxiliary substances (green chemistry principle 5, n = 107), waste prevention (green chemistry principle 1, n = 89), and the use of catalysts (green chemistry principle 9, n = 77). Some papers described the optimization of experimental work by also considering the following principles: design for energy efficiency (green chemistry principle 6, n = 71), use of renewable feedstock (green chemistry principle 7, n = 65), atom economy (green chemistry principle 2, n = 64), less hazardous synthesis (green chemistry principle 3, n = 62), inherently benign chemistry for accident prevention (green chemistry principle 12, n = 51), design for degradation (green chemistry principle 10, n = 30), and reduction of derivatives (green chemistry principle 8, n = 17), although to a lesser extent. In the reviewed papers, the principles of designing safer chemicals (green chemistry principle 4, n = 14) and real-time analysis for pollution prevention (green chemistry principle 11, n = 10) were the least covered, which is not surprising given that these two principles are usually excluded from teaching experiments because laboratory work does not involve the production of new products [83,100].

It is interesting to note that more than half of the papers (58.94%) considered one (n = 49), two (n = 58), or three (n = 48) green chemistry principles, and only some (4.56%) considered experimental work from green chemistry perspectives more holistically in terms of the many features that must be considered when the "greenness" of a chemical reaction is discussed. In this context, some papers addressed ten (n = 7), eleven (n = 2), or all green chemistry principles (n = 4, Table 9).

Table 8. Number of papers dealing with experimental work from green chemistry perspectives published between 1995 and 2020 according to the 12 green chemistry principles that they address.

Green Chemistry Principle	Frequency *	Paper Code
GC Principle 5: Safer solvents & auxiliaries.	107	S2, S9, S10, S13, S19, S20, S23, S25, S30, S37-S42, S44, S47, S53, S54, S58, S61, S62, S64-S68, S74, S78-S80, S82, S84-S86, S90-S92, S103, S106, S108, S110, S112, S116, S117, S122, S123, S125, S128, S130, S132, S134-S137, S139, S141, S145, S147, S153-S156, S160-S162, S165-S167, S169, S170, S176-S180, S182, S183, S186, S190, S191, S193, S198, S201, S203, S204, S210, S222, S226, S228, S229, S232, S233, 2W, 3W, 5W-7W, 10W, 1E, 2E, 4E, 6E, 8E, 9E, 11E, 17E
GC Principle 1: Prevent waste.	89	S10, S14, S18-S20, S32, S33, S38, S41, S49, S53, S55, S56, S62, S64, S66, S67, S69-S71, S74, S82, S91, S93, S102-S105, S110, S112, S117, S118, S120, S121, S124, S126, S128-S130, S133, S135-S141, S144-S146, S149, S153, S156, S163, S165, S167-S169, S176, S184, S191, S193, S194, S199, S200, S204, S210, S222, S226-S228, 3W, 5W-9W, 11W, 1E-3E, 6E-8E, 10E, 12E, 16E, 18E, 19E
GC Principle 9: Catalysis.	77	S9, S16-S21, S35, S36, S40, S41, S43, S44, S46, S47, S56, S60, S61, S64, S66, S69, S74, S78, S80, S81, S89, S90, S93, S103, S114-S117, S120, S121, S125, S130, S134, S136, S137, S144, S146, S150, S156, S165, S167, S169, S171, S177, S181, S186, S187, S189, S193, S196, S200, S203, S204, S210, S221, S223, S226, S233, 1W-5W, 7W, 9W, 10W, 3E, 5E, 6E, 14E, 17E, 19E
GC Principle 6: Design for energy efficiency.	71	S2, S5, S7, S9, S10, S19, S20, S22, S25, S30, S37, S39, S43, S49, S53, S54, S61, S64, S66, S67, S74, S85, S90, S93, S103, S117, S120, S127, S130, S132, S136, S137, S139, S141, S142, S144, S146, S147, S155, S158, S166, S167, S169, S172, S175, S181, S182, S184, S190, S192-S194, S202, S203, S205, S210, S226, S227, S229, S233, 1W, 5W, 6W, 7W, 8W, 10W, 2E, 3E, 4E, 6E, 10E, 19E
GC Principle 7: Use of renewable feedstock.	65	S2, S10, S13, S19-S24, S28-S30, S59, S63, S64, S66, S74, S89, S91, S93, S98, S103, S106, S107, S117, S118, S120, S126, S129, S133, S136, S141, S149, S156, S158, S160, S167, S169, S171, S173, S177, S179, S184-S187, S189, S192, S200, S203, S204, S210, S226, S230, 2W, 4W, 5W-7W, 9W, 5E, 6E, 13E, 18E
GC Principle 2: Atom economy.	64	S2, S5, S10, S14, S18-S20, S25, S29, S32, S38, S47, S52, S62, S64, S66, S67, S70, S71, S74, S78, S82, S90, S103, S110, S115, S120, S121, S128, S130, S133, S136, S137, S139, S145, S146, S167-S169, S182, S192-S194, S203-S205, S210, S219, S222, S226-S228, 1W, 2W, 5W-7W, 9W, 10W, 4E, 6E, 8E, 12E, 17E
GC Principle 3: Less hazardous synthesis.	62	S2, S10, S19-S21, S25, S29, S31, S33, S38, S45, S64, S66, S69, S74, S88, S92, S103-S105, S108, S110-S112, S117, S118, S121, S128, S130, S131, S136, S137, S139, S141, S144, S147, S152, S154, S164, S165, S167, S169, S174, S180, S181, S185, S188, S198, S210, 5W, 7W, 8W, 10W, 11W, 4E, 6E, 10E-12E, 15E, 16E, 18E
GC Principle 12: Inherently benign chemistry for accident prevention.	51	S2, S19, S20, S30, S31, S33, S35, S64, S66, S74, S91, S92, S103, S112, S118, S126, S127, S131, S134-S141, S144, S147, S152, S162-S167, S169, S174, S176, S198, S199, S202, S210, S226, 5W, 7W, 8W, 10W, 2E, 6E, 8E, 11E, 16E
GC Principle 10: Design for degradation.	30	S2, S10, S13, S19, S20, S23, S30, S35, S64, S66, S74, S91, S103, S106, S107, S111, S120, S144, S160, S167, S169, S177, S179, S186, S200, S210, S226, 5W, 7W, 6E
GC Principle 8: Reduce derivatives.	17	S19, S20, S64, S66, S74, S103, S120, S139, S162, S167, S169, S187, S210, S226, 5W, 7W, 6E
GC Principle 4: Design safer chemicals.	14	S2, S10, S14, S17, S19, S20, S32, S103, S119, S139, S192, S210, S226, 8W
GC Principle 11: Real-time analysis for pollution prevention.	10	S10, S19, S20, S58, S103, S147, S167, S169, S210, 10W
General	21	S72, S73, S75, S83, S143, S148, S151, S159, S195, S206, S207, S209, S211, S212, S214, S216, S217, S218, S220, S224, S225
Not defined specifically	33	S1, S3, S4, S6, S8, S11, S12, S15, S26, S27, S34, S48, S50, S51, S57, S76, S77, S87, S94-S97, S99-S101, S109, S113, S157, S197, S208, S213, S215, S231

Note: * Some reviewed papers may address more than one principle of green chemistry.

Table 9. Number of papers dealing with experimental work from green chemistry perspectives published between 1995 and 2020 according to the number of green chemistry principles they address.

No. of Green Chemistry Principles Addressed in the Papers	Frequency	Paper Code
2	58	S5, S17, S22, S31, S37, S39, S40, S43, S44, S49, S54, S56, S58, S70, S71, S80, S85, S89, S104, S105, S107, S108, S111, S115, S116, S125, S127, S129, S131, S132, S138, S140, S149, S152-S155, S158, S163, S164, S166, S168, S171, S174, S180, S185, S189-S191, S199, S202, S205, S229, S233, 4W, 11W, 1E, 5E
1	49	S7, S16, S24, S28, S36, S42, S45, S46, S52, S55, S59, S60, S63, S65, S68, S79, S81, S84, S86, S88, S98, S102, S114, S119, S122-S124, S142, S150, S161, S170, S172, S173, S175, S178, S183, S188, S196, S201, S219, S221, S223, S230, S232, 7E, 9E, 13E-15E
3	48	S9, S13, S14, S18, S21, S23, S29, S32, S33, S35, S41, S47, S53, S61, S62, S69, S78, S82, S92, S106, S126, S133-S135, S145, S160, S162, S176, S179, S181, S182, S184, S187, S194, S198, S222, S227, S228, 1W, 3W, 3E, 10E-12E, 16E-19E
4	21	S25, S38, S67, S90, S93, S110, S112, S118, S121, S128, S146, S156, S177, S186, S192, S200, 2W, 9W, 2E, 4E, 8E
5	9	S30, S91, S147, S165, S193, S203, S204, 6W, 8W
10	7	S64, S66, S74, S226, 5W, 7W, 6E
6	4	S117, S130, S141, S144
12	4	S19, S20, S103, S210
7	3	S120, S137, 10W
8	3	S2, S136, S139
11	2	S167, S169
9	1	S10
General	21	S72, S73, S75, S83, S143, S148, S151, S159, S195, S206, S207, S209, S211, S212, S214, S216-S218, S220, S224, S225
Not defined specifically	33	S1, S3, S4, S6, S8, S11, S12, S15, S26, S27, S34, S48, S50, S51, S57, S76, S77, S87, S94-S97, S99, S100, S101, S109, S113, S157, S197, S208, S213, S215, S231
Total	263	

4. Discussion and Conclusions

4.1. Key Findings and Implications

This systematic literature review was conducted to provide an overview and insight into the research literature on laboratory experimental work related to green chemistry to support quality education by engaging students in experimental activities according to the fourth SDG from the Agenda 2030 framework. In order to facilitate the development of this important topic for future science education, the review aimed to derive information on the purposes for implementation of green chemistry in science education experimental work at all education levels and how these learning activities are predominantly performed. The novelty of the present paper is its attempt to reach a holistic perspective by involving all fields of chemistry, all education levels, and the 12 green chemistry principles from the previous 25 years of literature. Special attention was given to green chemistry education in relation to experimental work, addressing both pre- and in-service teachers.

For the purposes of this paper, a total of 263 papers resulting from the literature review following the 2020 PRISMA guidelines were analyzed to answer the set objectives and proposed research questions.

The results indicate that from 2011 onwards, there was a significant wave of publication of scientific papers about the implementation of green chemistry in laboratory experimental work, especially in the form of experience reports, which point to many examples of good teaching practices. This finding is consistent with the increased number of publications in the wider field targeting green chemistry [68]. The primary field of chemistry covered in the papers is organic chemistry, as also described in the previous literature on the subject [12,52]. Over the years, the reviewed literature has responded to the need to develop educational materials for other fields of chemistry, particularly analytical, environmental, and physical chemistry. In doing so, many researchers [68,96] have pointed out the need to integrate green chemistry into existing curricula and teaching materials.

The results of the literature review suggest that updating chemistry teaching and learning with laboratory experimental work optimized from green chemistry perspectives simultaneously provides a safer approach to chemistry and ensures a safer environment by minimizing exposure to potentially hazardous chemicals and reducing the generated waste. Aubrecht et al. [27] pointed out the importance of teaching chemical safety by recognizing a significant overlap between reflection on the 12 green chemistry principles and the RAMP paradigm (recognize hazards, assess the risks of hazards, minimize the risks of hazards, and prepare for emergencies) [80].

Regarding the use of green chemistry in laboratory experimental work in science education at different education levels, our study revealed that it is used much more frequently in tertiary education compared with secondary and primary education. This finding is consistent with other recent studies that emphasize the need for novel activities, experiments, and case studies [24] in secondary and primary education, and highlight that incorporating green chemistry concepts into all education levels from primary to tertiary could be of great benefit to education as a whole [12,52]. Moreover, the present study also indicates the lack of research regarding the implementation of green chemistry in pre- and in-service teacher education.

The 12 green chemistry principles were referred to directly or indirectly in the reviewed papers. The results show that some of the green chemistry principles are predominantly used in the optimization of experimental work, e.g., the substitution of solvents and other auxiliary substances (green chemistry principle 5), waste prevention (green chemistry principle 1), and the use of catalysts (green chemistry principle 9). When analyzing the number of green chemistry principles addressed in each reviewed paper in the systematic literature review, it can be seen that most papers target one to three principles. Although not all principles were considered in most cases, it is important to keep in mind that even the application of a single green chemistry principle can make a big difference in experimental work. Therefore, the number of green chemistry principles involved should not be understood as just "all or nothing," but rather a striving for "the more, the better." It is important to develop students' green chemistry skills by asking simple questions, such as (1) "What is green about the experiment?"; (2) "What is not green?" and (3) "How could the experiment be optimized to be greener?" [12,52].

As a lack of studies on the integration of green chemistry principles into laboratory experimental work in secondary and primary education was identified, it would be beneficial to devote more attention to these education levels in the future. For example, it would be very valuable to develop teaching materials to support primary and secondary teachers in introducing green chemistry experimental work in their classes. Due to the crucial role of teachers in achieving the fourth SDG from the 2030 Agenda, special emphasis should be given to pre- and in-service teacher education, including didactical courses and corresponding teaching materials dealing with various possibilities for implementation of experimental work from green chemistry perspectives into the educational process at all education levels.

4.2. Limitations

The recently updated PRISMA guidelines were followed in this systematic literature review to make the results replicable and scientifically adequate. Three electronic databases (Scopus, WoS, and ERIC) were used in an attempt to identify as many eligible studies as possible to provide the broadest overview of laboratory experimental work related to green chemistry. However, by selecting only three electronic databases, potentially relevant publications may have been overlooked due to bias in the selection of databases or in the search terms used to identify eligible studies. In addition, review papers are usually limited by publication bias [101]. Furthermore, our systematic literature review is subject to language bias, as only English-language papers were included in the analysis.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Papers included in systematic literature review.

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S1	Abraham, L.; Stachow, L; Du, H.	2020	*Journal of Chemical Education*	Cinnamon Oil: An Alternate and Inexpensive Resource for Green Chemistry Experiments in Organic Chemistry Laboratory	[42]
S2	Abraham, L.	2020	*Journal of Chemical Education*	A Green Nucleophilic Aromatic Substitution Reaction	[102]
S3	Alberich, A.; Serrano, N.; Díaz-Cruz, J.M.; Ariño, C.; Esteban, M.	2013	*Journal of Chemical Education*	Substitution of mercury electrodes by bismuth-coated screen-printed electrodes in the determination of quinine in tonic water	[103]
S4	Ali, Z.M.; Harris, V.H.; Lalonde, R.L.	2020	*Journal of Chemical Education*	Beyond Green Chemistry: Teaching Social Justice in Organic Chemistry	[104]
S5	Alwaseem, H.; Donahue, C.J.; Marincean, S.	2014	*Journal of Chemical Education*	Catalytic transfer hydrogenation of castor oil	[105]
S6	Amaris, Z.N.; Freitas, D.N.; Mac, K.; Gerner, K.T.; Nameth, C.; Wheeler, K.E.	2017	*Journal of Chemical Education*	Nanoparticle Synthesis, Characterization, and Ecotoxicity: A Research-Based Set of Laboratory Experiments for a General Chemistry Course	[106]
S7	Amin, S.; Barnes, A.; Buckner, C.; Jones, J.; Monroe, M.; Nurmomade, L.; Pinto, T.; Starkey, S.; Agee, B.M.; Crouse, D.J.; Swartling, D.J.	2015	*Journal of Chemical Education*	Diels-alder reaction using a solar irradiation heat source designed for undergraduate organic chemistry laboratories	[107]
S8	Andraos, J.; Dicks, A.P.	2012	*Chemistry Education Research and Practice*	Green chemistry teaching in higher education: A review of effective practices	[12]
S9	Armstrong, C.; Burnham, J.A.J.; Warminski, E.E.	2017	*Journal of Chemical Education*	Combining Sustainable Synthesis of a Versatile Ruthenium Dihydride Complex with Structure Determination Using Group Theory and Spectroscopy	[108]
S10	Armstrong, L.B.; Rivas, M.C.; Zhou, Z.; Irie, L.M.; Kerstiens, G.A.; Robak, M.T.; Douskey, M.C.; Baranger, A.M.	2019	*Journal of Chemical Education*	Developing a Green Chemistry Focused General Chemistry Laboratory Curriculum: What Do Students Understand and Value about Green Chemistry?	[28]
S11	Arrebola, J.C.; Rodríguez-Fernández, N.; Caballero, Á.	2020	*Journal of Chemical Education*	Decontamination of Wastewater Using Activated Biochar from Agricultural Waste: A Practical Experiment for Environmental Sciences Students	[109]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S12	Aubrecht, K.B.; Bourgeois, M.; Brush, E.J.; Mackellar, J.; Wissinger, J.E.	2019	*Journal of Chemical Education*	Integrating Green Chemistry in the Curriculum: Building Student Skills in Systems Thinking, Safety, and Sustainability	[27]
S13	Aubrecht, K.B.; Padwa, L.; Shen, X.; Bazargan, G.	2015	*Journal of Chemical Education*	Development and implementation of a series of laboratory field trips for advanced high school students to connect chemistry to sustainability	[110]
S14	Bachofer, S.J.; Lingwood, M.D.	2019	*Physical Sciences Reviews*	A green determination of an equilibrium constant: teaching new skills	[111]
S15	Bailey, A.; Andrews, L.; Khot, A.; Rubin, L.; Young, J.; Allston, T.D.; Takacs, G.A.	2015	*Journal of Chemical Education*	Hydrogen storage experiments for an undergraduate laboratory course-clean energy: Hydrogen/fuel cells	[112]
S16	Ballard, C.E.	2013	*Journal of Chemical Education*	Green oxidative homocoupling of 1-methylimidazole	[113]
S17	Ballard, C.E.	2011	*Journal of Chemical Education*	Green reductive homocoupling of bromobenzene	[114]
S18	Bannin, T.J.; Datta, P.P.; Kiesewetter, E.T.; Kiesewetter, M.K.	2019	*Journal of Chemical Education*	Synthesizing Stilbene by Olefin Metathesis Reaction Using Guided Inquiry to Compare and Contrast Wittig and Metathesis Methodologies	[115]
S19	Barcena, H.; Maziarz, K.	2017	*Journal of Chemical Education*	Chemical upcycling of expired drugs: Synthesis of guaifenesin acetonide	[116]
S20	Barcena, H.; Tuachi, A.; Zhang, Y.	2017	*Journal of Chemical Education*	Teaching Green Chemistry with Epoxidized Soybean Oil	[117]
S21	Behnia, M.S.; Emerson, D.W.; Steinberg, S.M.; Alwis, R.M.; Duenas, J.A.; Serafino, J.O.	2011	*Journal of Chemical Education*	A simple, safe method for preparation of biodiesel	[118]
S22	Bendall, S.; Birdsall-Wilson, M.; Jenkins, R.; Chew, Y.M.J.; Chuck, C.J.	2015	*Journal of Chemical Education*	Showcasing chemical engineering principles through the production of biodiesel from spent coffee grounds	[119]
S23	Bennett, G.D.	2005	*Journal of Chemical Education*	A green polymerization of aspartic acid for the undergraduate organic laboratory	[120]
S24	Berger, M.; Karod, M.; Goldfarb, J.L.	2019	*Physical Sciences Reviews*	Invasive species or sustainable water filters? A student-led laboratory investigation into locally sourced biomass-based adsorbents for sustainable water treatment	[121]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S25	Biswas, R.; Mukherjee, A.	2017	*Journal of Chemical Education*	Introducing the Concept of Green Synthesis in the Undergraduate Laboratory: Two-Step Synthesis of 4-Bromoacetanilide from Aniline	[122]
S26	Blatti, J.L.; Garcia, J.; Cave, D.; Monge, F.; Cuccinello, A.; Portillo, J.; Juarez, B.; Chan, E.; Schwebel, F.	2019	*Journal of Chemical Education*	Systems Thinking in Science Education and Outreach toward a Sustainable Future	[92]
S27	Blatti, J.L.	2017	*Journal of Chemical Education*	Colorful and Creative Chemistry: Making Simple Sustainable Paints with Natural Pigments and Binders	[94]
S28	Blatti, J.L.; Burkart, M.D.	2012	*Journal of Chemical Education*	Releasing stored solar energy within pond scum: Biodiesel from algal lipids	[123]
S29	Bodsgard, B.R.; Lien, N.R.; Waulters, Q.T.	2016	*Journal of Chemical Education*	Liquid CO_2 Extraction and NMR Characterization of Anethole from Fennel Seed: A General Chemistry Laboratory	[124]
S30	Buckley, H.L.; Beck, A.R.; Mulvihill, M.J.; Douskey, M.C.	2013	*Journal of Chemical Education*	Fitting it all in: Adapting a green chemistry extraction experiment for inclusion in an undergraduate analytical laboratory	[70]
S31	Cacciatore, K.L.; Amado, J.; Evans, J.J.; Sevian, H.	2008	*Journal of Chemical Education*	Connecting solubility, equilibrium, and periodicity in a green, inquiry experiment for the general chemistry laboratory	[125]
S32	Cacciatore, K.L.; Sevian, H.	2006	*Journal of Chemical Education*	Teaching lab report writing through inquiry: A green chemistry stoichiometry experiment for general chemistry	[126]
S33	Cardinal, P.; Greer, B.; Luong, H.; Tyagunova, Y.	2012	*Journal of Chemical Education*	A multistep synthesis incorporating a green bromination of an aromatic ring	[71]
S34	Cavalcante Dos Santos, R.; Cabral Cavalcanti, J.N.; Werneck Do Carmo, E.C.; De Souza, F.C.; Soares, W.G.; Gimenes De Souza, C.; França De Andrade, D.; D'Avila, L.A.	2020	*Journal of Chemical Education*	Approaching Diesel Fuel Quality in Chemistry Lab Classes: Undergraduate Student's Achievements on Determination of Biodiesel Content in Diesel Oil Applying Solvatochromic Effect	[127]
S35	Chan, J.M.W.; Zhang, X.; Brennan, M.K.; Sardon, H.; Engler, A.C.; Fox, C.H.; Frank, C.W.; Waymouth, R.M.; Hedrick, J.L.	2015	*Journal of Chemical Education*	Organocatalytic ring-opening polymerization of trimethylene carbonate to yield a biodegradable polycarbonate	[128]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S36	Chapman, S.; Herniman, J.M.; Langley, G.J.; Raja, R.; Logothetis, T.A.	2019	*Journal of Chemical Education*	Redox Aluminophosphates: Applying Fundamental Undergraduate Theory to Solve Global Challenges in the Chemical Industry	[129]
S37	Chemat, F.; Perino-Issartier, S.; Petitcolas, E.; Fernandez, X.	2012	*Analytical and Bioanalytical Chemistry*	"In situ" extraction of essential oils by use of Dean-Stark glassware and a Vigreux column inside a microwave oven: A procedure for teaching green analytical chemistry	[130]
S38	Cheney, M.L.; Zaworotko, M.J.; Beaton, S.; Singer, R.D.	2008	*Journal of Chemical Education*	Cocrystal controlled solid-state synthesis. A green chemistry experiment for undergraduate organic chemistry	[131]
S39	Cheung, L.L.W.; Styler, S.A.; Dicks, A.P.	2010	*Journal of Chemical Education*	Rapid and convenient synthesis of the 1,4-dihydropyridine privileged structure	[132]
S40	Christensen, J.E.; Huddle, M.G.; Rogers, J.L.; Yung, H.; Mohan, R.S.	2008	*Journal of Chemical Education*	The discovery-oriented approach to organic chemistry. 7. Rearrangement of trans-stilbene oxide with bismuth trifluoromethanesulfonate and other metal triflates: A microscale green organic chemistry laboratory experiment	[133]
S41	Clark, R.A.; Stock, A.E.; Zovinka, E.P.	2012	*Journal of Chemical Education*	Metalloporphyrins as oxidation catalysts: Moving toward "greener" chemistry in the inorganic chemistry laboratory	[134]
S42	Colacino, E.; Dayaker, G.; Morère, A.; Friščić, T.	2019	*Journal of Chemical Education*	Introducing Students to Mechanochemistry via Environmentally Friendly Organic Synthesis Using a Solvent-Free Mechanochemical Preparation of the Antidiabetic Drug Tolbutamide	[135]
S43	Colmenares, J.C.; Arévalo-García, E.B.; Colmenares-Quintero, R.F.	2015	*Journal of Science Education*	A simple method of water purification and energy extraction from organic wastewater: An application of green chemistry principles in everyday life	[20]
S44	Contreras-Cruz, D.A.; Cantú-Reyes, M.; García-Sánchez, J.M.; Peña-Ortíz, D.; Sánchez-Carmona, M.A.; Miranda, L.D.	2019	*Journal of Chemical Education*	Shedding blue light on the undergraduate laboratory: an easy-to-assemble LED Photoreactor for Aromatization of a 1,4-Dihydropyridine	[136]
S45	Cooper, P.D.; Walser, J.	2019	*Journal of Chemical Education*	Total Chemical Footprint of an Experiment: A Systems Thinking Approach to Teaching Rovibrational Spectroscopy	[137]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S46	Cosio, M.N.; Cardenal, A.D.; Maity, A.; Hyun, S.-M.; Akwaowo, V.E.; Hoffman, C.W.; Powers, T.M.; Powers, D.C.	2020	*Journal of Chemical Education*	Exploring Green Chemistry with Aerobic Hypervalent Iodine Catalysis	[138]
S47	Costa, N.E.; Pelotte, A.L.; Simard, J.M.; Syvinski, C.A.; Deveau, A.M.	2012	*Journal of Chemical Education*	Discovering green, aqueous Suzuki coupling reactions: Synthesis of ethyl (4-phenylphenyl)acetate, a biaryl with anti-arthritic potential	[139]
S48	Desmond, S.; Ray, C.; Andino Martínez, J.G.	2019	*Physical Sciences Reviews*	Educational benefits of green chemistry	[140]
S49	Dhingra, S.; Angrish, C.	2011	*Journal of Chemical Education*	Qualitative organic analysis: An efficient, safer, and economical approach to preliminary tests and functional group analysis	[141]
S50	Dias, A.M.; Ferreira, M.L.S.	2015	*Journal of Chemical Education*	"Supermarket column chromatography of leaf pigments" revisited: Simple and ecofriendly separation of plant carotenoids, chlorophylls, and flavonoids from green and red leaves	[93]
S51	Dicks, A.P.; D'Eon, J.C.; Morra, B.; Kutas Chisu C.; Quinlan, K.B.; Cannon, A.S.	2019	*Journal of Chemical Education*	A Systems Thinking Department: Fostering a Culture of Green Chemistry Practice among Students	[142]
S52	Dicks, A.P.	2018	*Current Opinion in Green and Sustainable Chemistry*	Teaching reaction efficiency through the lens of green chemistry: Should students focus on the yield, or the process?	[55]
S53	Dicks, A.P.	2009	*Green Chemistry Letters and Reviews*	Solvent-free reactivity in the undergraduate organic laboratory	[56]
S54	Dicks, A.P.	2009	*Green Chemistry Letters and Reviews*	A review of aqueous organic reactions for the undergraduate teaching laboratory	[57]
S55	Dintzner, M.R.; Kinzie, C.R.; Pulkrabek, K.; Arena, A.F.	2012	*Journal of Chemical Education*	The cyclohexanol cycle and synthesis of nylon 6,6: Green chemistry in the undergraduate organic laboratory	[143]
S56	Dintzner, M.R.; Maresh, J.J.; Kinzie, C.R.; Arena, A.F.; Speltz, T.	2012	*Journal of Chemical Education*	A research-based undergraduate organic laboratory project: Investigation of a one-pot, multicomponent, environmentally friendly prins-friedel-crafts-type reaction	[144]
S57	Divya, D.; Raj, K.G.	2019	*Journal of Chemical Education*	From Scrap to Functional Materials: Exploring Green and Sustainable Chemistry Approach in the Undergraduate Laboratory	[145]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S58	Dorney, K.M.; Baker, J.D.; Edwards, M.L.; Kanel, S.R.; O'Malley, M.; Sizemore, I.E.P.	2014	*Journal of Chemical Education*	Tangential flow filtration of colloidal silver nanoparticles: A "green" laboratory experiment for chemistry and engineering students	[146]
S59	dos Santos, R.V.; Viana, G.M.; Moreira, A.F.S.; Nóbrega, V.S.; da Silva, V.A.S.; Malta, L.F.B.; Aguiar; L.C.S.; Senra, J.D.	2019	*Quimica Nova*	Revisiting the nucleophilicity concept in a comprehensive biomass valorization experiment: From papaya seeds to thiourea motifs	[147]
S60	Duangpummet, P.; Chaiyen, P.; Chenprakhon, P.	2019	*Journal of Chemical Education*	Lipase-Catalyzed Esterification: An Inquiry-Based Laboratory Activity to Promote High School Students' Understanding and Positive Perceptions of Green Chemistry	[72]
S61	Edgar, L.J.G.; Koroluk, K.J.; Golmakani, M.; Dicks, A.P.	2014	*Journal of Chemical Education*	Green chemistry decision-making in an upper-level undergraduate organic laboratory	[148]
S62	Eissen, M.	2012	*Chemistry Education Research and Practice*	Sustainable production of chemicals—an educational perspective	[149]
S63	Félix, S.; Araújo, J.; Pires, A.M.; Sousa, A.C.	2017	*Waste Management*	Soap production: A green prospective	[150]
S64	Fennie, M.W.; Roth, J.M.	2016	*Journal of Chemical Education*	Comparing Amide-Forming Reactions Using Green Chemistry Metrics in an Undergraduate Organic Laboratory	[82]
S65	Förster, C.; Heinze, K.	2020	*Journal of Chemical Education*	Preparation and Thermochromic Switching between Phosphorescence and Thermally Activated Delayed Fluorescence of Mononuclear Copper(I) Complexes	[151]
S66	Gabriela, M.; Ribeiro, T.C.; MacHado, A.A.S.C.	2011	*Journal of Chemical Education*	Metal-acetylacetonate synthesis experiments: Which is greener?	[83]
S67	Garner, N.; Siol, A.; Eilks, I.	2016	*Journal of Science Education*	The synthesis of vanillin—learning about aspects of sustainable chemistry by comparing different syntheses	[73]
S68	Geiger, H.C.; Donohoe, J.S.	2012	*Journal of Chemical Education*	Green oxidation of menthol enantiomers and analysis by circular dichroism spectroscopy: An advanced organic chemistry laboratory	[152]
S69	Ginzburg, A.L.; Baca, N.A.; Hampton, P.D.	2014	*Journal of Chemical Education*	The Isomerization of (−)-Menthone to (+)-Isomenthone Catalyzed by an Ion-Exchange Resin	[74]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S70	Go, E.B.; Srisuknimit, V.; Cheng, S.L.; Vosburg, D.A.	2016	*Journal of Chemical Education*	Self-Assembly, Guest Capture, and NMR Spectroscopy of a Metal-Organic Cage in Water	[153]
S71	Gómez-Biagi, R.F.; Dicks, A.P.	2015	*Journal of Chemical Education*	Assessing Process Mass Intensity and Waste via an aza-Baylis-Hillman Reaction	[81]
S72	Goodwin, T.E.	2004	*Journal of Chemical Education*	An asymptotic approach to the development of a green organic chemistry laboratory	[154]
S73	Graham, K.J.; Jones, T.N.; Schaller, C.P.; McIntee, E.J.	2014	*Journal of Chemical Education*	Implementing a student-designed green chemistry laboratory project in organic chemistry	[75]
S74	Grieger, K.; Leontyev, A.	2020	*Journal of Chemical Education*	Promoting student awareness of green chemistry principles via student-generated presentation videos	[90]
S75	Günter, T.; Akkuzu, N.; Alpat, Ş.	2017	*Research in Science and Technological Education*	Understanding 'green chemistry' and 'sustainability': an example of problem-based learning (PBL)	[155]
S76	Guron, M.; Paul, J.J.; Roeder, M.H.	2016	*Journal of Chemical Education*	Incorporating Sustainability and Life Cycle Assessment into First-Year Inorganic Chemistry Major Laboratories	[88]
S77	Haack, J.A.; Hutchison, J.E.; Kirchhoff, M.M.; Levy, I.J.	2005	*Journal of Chemical Education*	Going green: Lecture assignments and lab experiences for the college curriculum	[11]
S78	Hamilton, A.E.; Buxton, A.M.; Peeples, C.J.; Chalker, J.M.	2013	*Journal of Chemical Education*	An operationally simple aqueous Suzuki-Miyaura cross-coupling reaction for an undergraduate organic chemistry laboratory	[156]
S79	Hie, L.; Chang, J.J.; Garg, N.K.	2015	*Journal of Chemical Education*	Nickel-catalyzed Suzuki-Miyaura cross-coupling in a green alcohol solvent for an undergraduate organic chemistry laboratory	[157]
S80	Hill, N.J.; Bowman, M.D.; Esselman, B.J.; Byron, S.D.; Kreitinger, J.; Leadbeater, N.E.	2014	*Journal of Chemical Education*	Ligand-free suzuki-miyaura coupling reactions using an inexpensive aqueous palladium source: A synthetic and computational exercise for the undergraduate organic chemistry laboratory	[158]
S81	Hill, N.J.; Hoover, J.M.; Stahl, S.S.	2013	*Journal of Chemical Education*	Aerobic alcohol oxidation using a copper(I)/TEMPO catalyst system: A green, catalytic oxidation reaction for the undergraduate organic chemistry laboratory	[159]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S82	Hoang, G.T.; Kubo, T.; Young, V.G., Jr.; Kautzky, J.A.; Wissinger, J.E.	2015	*Journal of Chemical Education*	Illustrating the Utility of X-ray Crystallography for Structure Elucidation through a Tandem Aldol Condensation/Diels-Alder Reaction Sequence	[160]
S83	Hoffman, K.C.; Dicks, A.P.	2020	*Sustainable Chemistry and Pharmacy*	Shifting the paradigm of chemistry education by Greening the high school laboratory	[23]
S84	Hopson, R.; Lee, P.Y.B.; Hess, K.M.	2018	*Journal of Chemical Education*	1-Dimensional Selective Nuclear Overhauser Effect NMR Spectroscopy to Characterize Products from a Two-Step Green Chemistry Synthesis	[161]
S85	Horta, J.E.	2011	*Journal of Chemical Education*	Simple microwave-assisted Claisen and Dieckmann condensation experiments for the undergraduate organic chemistry laboratory	[162]
S86	Hudson, R.; Ackerman, H.M.; Gallo, L.K.; Gwinner, A.S.; Krauss, A.; Sears, J.D.; Bishop, A.; Esdale, K.N.; Katz, J.L.	2017	*Journal of Chemical Education*	CO_2 Dry Cleaning: A Benign Solvent Demonstration Accessible to K-8 Audiences	[21]
S87	Hurst, G.A.	2020	*Current Opinion in Green and Sustainable Chemistry*	Systems thinking approaches for international green chemistry education	[87]
S88	Hurst, G.A.	2017	*Journal of Chemical Education*	Green and Smart: Hydrogels to Facilitate Independent Practical Learning	[163]
S89	Hwang, H.L.; Jadhav, S.R.; Silverman, J.R.; John, G.	2014	*Journal of Chemical Education*	Sweet and Sustainable: Teaching the Biorefinery Concept through Biobased Gelator Synthesis	[164]
S90	Ison, E.A.; Ison, A.	2012	*Journal of Chemical Education*	Synthesis of well-defined copper N-heterocyclic carbene complexes and their use as catalysts for a "click reaction": A multistep experiment that emphasizes the role of catalysis in green chemistry	[165]
S91	Johnston, A.; Scaggs, J.; Mallory, C.; Haskett, A.; Warner, D.; Brown, E.; Hammond, K.; McCormick, M.M.; McDougal, O.M.	2013	*Journal of Chemical Education*	A green approach to separate spinach pigments by column chromatography	[166]
S92	Jones-Wilson, T.M.; Burtch, E.A.	2005	*Journal of Chemical Education*	A green starting material for electrophilic aromatic substitution for the undergraduate organic laboratory	[167]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S93	Josephson, P.; Nykvist, V.; Qasim, W.; Blomkvist, B.; DInér, P.	2019	*Journal of Chemical Education*	Student-Driven Development of Greener Chemistry in Undergraduate Teaching: Synthesis of Lidocaine Revisited	[76]
S94	Karpudewan, M.; Kulandaisamy, Y.	2018	*Current Opinion in Green and Sustainable Chemistry*	Malaysian teachers' insights into implementing green chemistry experiments in secondary schools	[99]
S95	Karpudewan, M.; Mathanasegaran, K.	2018	*Asia-Pacific Forum on Science Learning and Teaching*	Exploring the use of context-based green chemistry experiments in understanding the effects of concentration and catalyst on the rate of reaction	[168]
S96	Karpudewan, M.; Roth, W.-M.; Ismail, Z.	2013	*Asia-Pacific Education Researcher*	The Effects of "Green Chemistry" on Secondary School Students' Understanding and Motivation	[169]
S97	Karpudewan, M.; Ismail, Z.; Roth, W.-M.	2012	*Journal of Science Teacher Education*	Fostering Pre-service Teachers' Self-Determined Environmental Motivation Through Green Chemistry Experiments	[95]
S98	Karpudewan, M.; Ismail, Z.; Roth, W.-M.	2012	*Chemistry Education Research and Practice*	Ensuring sustainability of tomorrow through green chemistry integrated with sustainable development concepts (SDCs)	[96]
S99	Karpudewan, M.; Ismail, Z.; Roth, W.-M.	2012	*Environmental Education Research*	Promoting pro-environmental attitudes and reported behaviors of Malaysian pre-service teachers using green chemistry experiments	[97]
S100	Karpudewan, M.; Ismail, Z.H.; Mohamed, N.	2009	*International Journal of Sustainability in Higher Education*	The integration of green chemistry experiments with sustainable development concepts in pre-service teachers' curriculum: Experiences from Malaysia	[39]
S101	Keen, C.; Couture, S.; Abd El Meseh, N.; Sevian, H.	2020	*Journal of Chemical Education*	Connecting Theory to Life: Learning Greener Electrochemistry by Taking Apart a Common Battery	[170]
S102	Kelly, M.J.B.; Fallot, L.B.; Gustafson, J.L.; Bergdahl, B.M.	2016	*Journal of Chemical Education*	Water Mediated Wittig Reactions of Aldehydes in the Teaching Laboratory: Using Sodium Bicarbonate for the in Situ Formation of Stabilized Ylides	[171]
S103	Khuong, K.S.	2017	*Journal of Chemical Education*	Greener Oxidation of Benzhydrol: Evaluating Three Oxidation Procedures in the Organic Laboratory	[172]
S104	Klingshirn, M.A.; Wyatt, A.F.; Hanson, R.M.; Spessard, G.O.	2008	*Journal of Chemical Education*	Determination of the formula of a hydrate: A greener alternative	[173]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S105	Klotz, E., Doyle, R., Gross, E.; Mattson, B.	2011	*Journal of Chemical Education*	The equilibrium constant for bromothymol blue: A general chemistry laboratory experiment using spectroscopy	[174]
S106	Knutson, C.M.; Hilker, A.P.; Tolstyka, Z.P.; Anderson, C.B.; Wilbon, P.A.; Mathers, R.T.; Wentzel, M.T.; Perkins, A.L.; Wissinger, J.E.	2019	*Journal of Chemical Education*	Dyeing to Degrade: A Bioplastics Experiment for College and High School Classrooms	[175]
S107	Knutson, C.M.; Schneiderman, D.K.; Yu, M.; Javner, C.H.; Distefano, M.D.; Wissinger, J.E.	2017	*Journal of Chemical Education*	Polymeric Medical Sutures: An Exploration of Polymers and Green Chemistry	[176]
S108	Koch, A.S.; Chimento, C.A.; Berg, A.N.; Mughal, F.D.; Spencer, J.-P.; Hovland, D.E.; Mbadugha, B.; Hovland, A.K.; Eller, L.R.	2015	*Journal of Chemical Education*	Extraction of maltol from Fraser fir: A comparison of microwave-assisted extraction and conventional heating protocols for the organic chemistry laboratory	[177]
S109	Kolopajlo, L.	2017	*Physical Sciences Reviews*	Green chemistry pedagogy	[24]
S110	Koroluk, K.J.; Jackson, D.A.; Dicks, A.P.	2012	*Journal of Chemical Education*	The Petasis reaction: Microscale synthesis of a tertiary amine antifungal analog	[178]
S111	Kradtap Hartwell, S.	2012	*Chemistry Education Research and Practice*	Exploring the potential for using inexpensive natural reagents extracted from plants to teach chemical analysis	[179]
S112	Krenz, J.; Simcox, N.; Stoddard Tepe, J.; Simpson, C.D.	2016	*ACS Sustainable Chemistry and Engineering*	Transitioning to safer chemicals in academic research laboratories: Lessons learned at the University of Washington	[78]
S113	Kurowska-Susdorf, A.; Zwierżdżyński, M.; Bevanda, A.M.; Talić, S.; Ivanković, A.; Płotka-Wasylka, J.	2019	*TrAC—Trends in Analytical Chemistry*	Green analytical chemistry: Social dimension and teaching	[180]
S114	Lam, C.H.; Jackson, J.E.	2020	*Journal of Chemical Education*	Teaching Electrochemistry with Common Objects: Electrocatalytic Hydrogenation of Acetol with U.S. Coins	[181]
S115	Lam, C.H.; Escande, V.; Mellor, K.E.; Zimmerman, J.B.; Anastas, P.T.	2019	*Journal of Chemical Education*	Teaching Atom Economy and E-Factor Concepts through a Green Laboratory Experiment: Aerobic Oxidative Cleavage of meso-Hydrobenzoin to Benzaldehyde Using a Heterogeneous Catalyst	[84]
S116	Landstrom, E.B.; Nichol, M.; Lipshutz, B.H.; Gainer, M.J.	2019	*Journal of Chemical Education*	Discovery-Based S_NAr Experiment in Water Using Micellar Catalysis	[182]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S117	Lang, P.T.; Harned, A.M.; Wissinger, J.E.	2011	*Journal of Chemical Education*	Oxidation of borneol to camphor using oxone and catalytic sodium chloride: A green experiment for the undergraduate organic chemistry laboratory	[183]
S118	Lapanantnoppakhun, S.; Tengjaroensakul, U.; Mungkornasawakul, P.; Puangpila, C.; Kittiwachana, S.; Saengtempiam, J.; Hartwell, S.K.	2020	*Journal of Chemical Education*	Green Analytical Chemistry Experiment: Quantitative Analysis of Iron in Supplement Tablets with Vis spectrophotometry Using Tea Extract as a Chromogenic Agent	[184]
S119	Lasker, G.A.; Simcox, N.J.; Mellor, K.E.; Mullins, M.L.; Nesmith, S.M.; Van Bergen, S.; Anastas, P.T.	2019	*Journal of Chemical Education*	Introducing Toxicology into the Undergraduate Chemistry Laboratory Using Safety Data Sheets and Sunscreen Activities	[185]
S120	Lee, N.E.; Gurney, R.; Soltzberg, L.	2014	*Journal of Chemical Education*	Using green chemistry principles as a framework to incorporate research into the organic laboratory curriculum	[79]
S121	Leslie, J.M.; Tzeel, B.A.	2016	*Journal of Chemical Education*	Gold(III)-Catalyzed Hydration of Phenylacetylene	[186]
S122	Leslie, R.; Leeb, E.; Smith, R.B.	2012	*Journal of Chemical Education*	Synthesis of ethyl nalidixate: A medicinal chemistry experiment	[187]
S123	Leung, S.H.; Angel, S.A.	2004	*Journal of Chemical Education*	Solvent-free wittig reaction: A green organic chemistry laboratory experiment	[188]
S124	Lin, Y.; Zhao, H.; Yu, F.; Yang, J.	2018	*Sustainability*	Design of an extended experiment with electrical double layer capacitors: Electrochemical energy storage devices in green chemistry	[189]
S125	Lipshutz, B.H.; Bošković, Z.; Crowe, C.S.; Davis, V.K.; Whittemore, H.C.; Vosburg, D.A.; Wenzel, A.G.	2013	*Journal of Chemical Education*	"Click" and olefin metathesis chemistry in water at room temperature enabled by biodegradable micelles	[190]
S126	Listyarini, R.V.; Pamenang, F.D.N.; Harta, J.; Wijayanti, L.W.; Asy'ari, M.; Lee, W.	2019	*Jurnal Pendidikan IPA Indonesia*	The integration of green chemistry principles into small scale chemistry practicum for senior high school students	[16]
S127	Liu, Y.; Myers, E.J.; Rydahl, S.A.; Wang, X.	2019	*Journal of Chemical Education*	Ultrasonic-Assisted Synthesis, Characterization, and Application of a Metal-Organic Framework: A Green General Chemistry Laboratory Project	[191]
S128	Lu, G.-P.; Chen, F.; Cai, C.	2017	*Journal of Chemical Education*	Thiourea in the Construction of C-S Bonds as Part of an Undergraduate Organic Chemistry Laboratory Course	[192]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S129	Mackenzie, L.S.; Tyrrell, H.; Thomas, R.; Matharu, A.S.; Clark, J.H.; Hurst, G.A.	2019	*Journal of Chemical Education*	Valorization of Waste Orange Peel to Produce Shear-Thinning Gels	[193]
S130	Manchanayakage, R.	2013	*Journal of Chemical Education*	Designing and incorporating green chemistry courses at a liberal arts college to increase students' awareness and interdisciplinary collaborative work	[194]
S131	Marcos, C.F.; Neo, A.G.; Díaz, J.; Martínez-Caballero, S.	2020	*Journal of Chemical Education*	A Safe and Green Benzylic Radical Bromination Experiment	[195]
S132	Martin, E.; Kellen-Yuen, C.	2007	*Journal of Chemical Education*	Microwave-assisted organic synthesis in the organic lab: A simple, greener Wittig reaction	[196]
S133	McAllister, G.D.; Parsons, A.F.	2019	*Journal of Chemical Education*	Going Green in Process Chemistry: Optimizing an Asymmetric Oxidation Reaction to Synthesize the Antiulcer Drug Esomeprazole	[197]
S134	McKee, J.R.; Zanger, M.; Chiariello, C.; McKee, J.A.; Dorfner, W.; Fasella, E.; Koo, Y.	2019	*Journal of Chemical Education*	Semimicro/Microscale Adaptation of the Cobalt Chloride/Sodium Borohydride Reduction of Methyl Oleate	[198]
S135	McKenzie, L.C.; Huffman, L.M.; Parent, K.E.; Hutchison, J.E.; Thompson, J.E.	2004	*Journal of Chemical Education*	Patterning Self-Assembled Monolayers on Gold: Green Materials Chemistry in the Teaching Laboratory	[199]
S136	Mio, M.J.	2017	*Physical Sciences Reviews*	How the principles of green chemistry changed the way organic chemistry labs are taught at the university of detroit mercy	[200]
S137	Mohan, R.S.; Mejia, M.P.	2020	*Journal of Chemical Education*	Environmentally Friendly Organic Chemistry Laboratory Experiments for the Undergraduate Curriculum: A Literature Survey and Assessment	[201]
S138	Mooney, D.	2004	*Chemical Health and Safety*	Effectively minimizing hazardous waste in academia: The Green Chemistry approach	[202]
S139	Mooney, M.; Vreugdenhil, A.J.; Shetranjiwalla, S.	2020	*Journal of Chemical Education*	A Toolkit of Green Chemistry and Life-Cycle Analysis for Comparative Assessment in Undergraduate Organic Chemistry Experiments: Synthesis of (E)-Stilbene	[203]
S140	Morris, R.K.; Hilker, A.P.; Mattice, T.M.; Donovan, S.M.; Wentzel, M.T.; Willoughby, P.H.	2019	*Journal of Chemical Education*	Simple and Versatile Protocol for Preparing Self-Healing Poly(vinyl alcohol) Hydrogels	[204]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S141	Morsch, L.A.; Deak, L.; Tiburzi, D.; Schuster, H.; Meyer, B.	2014	*Journal of Chemical Education*	Green aqueous wittig reaction: Teaching green chemistry in organic teaching laboratories	[205]
S142	Mullins, J.J.; Prusinowski, A.F.	2019	*Journal of Chemical Education*	Microwave-Promoted Synthesis of a Carbocyclic Curcuminoid: An Organic Chemistry Laboratory Experiment	[206]
S143	Murphy, K.C.; Dilip, M.; Quattrucci, J.G.; Mitroka, S.M.; Andreatta, J.R.	2019	*Journal of Chemical Education*	Sustainable Consumer Choices: An Outreach Program Exploring the Environmental Impact of Our Consumer Choices Using a Systems Thinking Model and Laboratory Activities	[207]
S144	Narayan, S.	2020	*Physical Sciences Reviews*	Sustainability and some green initiatives in undergraduate education	[58]
S145	Nigam, M.; Rush, B.; Patel, J.; Castillo, R.; Dhar, P.	2016	*Journal of Chemical Education*	Aza-Michael Reaction for an Undergraduate Organic Chemistry Laboratory	[208]
S146	Obhi, N.K.; Mallov, I.; Borduas-Dedekind, N.; Rousseaux, S.A.L.; Dicks, A.P.	2019	*Journal of Chemical Education*	Comparing Industrial Amination Reactions in a Combined Class and Laboratory Green Chemistry Assignment	[209]
S147	Orwat, K.; Bernard, P.; Wróblewski, S.; Mendez, J.D.	2018	*Macedonian Journal of Chemistry and Chemical Engineering*	Traditional vs. UV-cured coatings—An inquiry-based experiment for introducing green chemistry	[77]
S148	Paluri, S.L.A.; Edwards, M.L.; Lam, N.H.; Williams, E.M.; Meyerhoefer, A.; Sizemore, I.E.P.	2015	*Journal of Chemical Education*	Introducing green and nongreen aspects of noble metal nanoparticle synthesis: An inquiry-based laboratory experiment for chemistry and engineering students	[210]
S149	Panda, D.; Patra, S.; Awasthi, M.K.; Singh, S.K.	2020	*ACS applied materials & interfaces*	Lab Cooked MOF for CO_2 Capture: A Sustainable Solution to Waste Management	[211]
S150	Pandarus, V.; Ciriminna, R.; Béland, F.; Pagliaro, M.	2020	*Applied Materials Today*	Making fine chemicals, nanomaterials and pharmaceutical ingredients over SiliaCat catalysts	[212]
S151	Panzarasa, G.	2018	*ACS Omega*	Just Add Luminol to Turn the Spotlight on Radziszewski Amidation	[213]
S152	Panzarasa, G.; Sparnacci, K.	2012	*Journal of Chemical Education*	Glowing teacup demonstration: Trautz-schorigin reaction of natural polyphenols	[214]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S153	Patterson, A.L.; May, M.D.; Visser, B.J.; Kislukhin, A.A.; Vosburg, D.A.	2013	*Journal of Chemical Education*	Solvent-free synthesis and fluorescence of a thiol-reactive sensor for undergraduate organic laboratories	[215]
S154	Peng, H.-C.; Bryan, J.; Henson, W.; Zhdankin, V.V.; Gandhi, K.; David, S.	2019	*Journal of Chemical Education*	New, Milder Hypervalent Iodine Oxidizing Agent: Using μ-Oxodi(phenyliodanyl) Diacetate, a (Diacetoxyiodo)benzene Derivative, in the Synthesis of Quinones	[216]
S155	Pereira, T.M.;Franco, D.F.P.; Vitório, F.; Amaral, R.C.; Ponzoni, A.C.; Kümmerle, A.E.	2018	*Quimica Nova*	Microwave-assisted synthesis and pka determination of umbelliferone: An experiment for the undergraduate organic chemistry laboratory	[217]
S156	Pfab, E.; Filiciotto, L.; Luque, R.	2019	*Journal of Chemical Education*	The Dark Side of Biomass Valorization: A Laboratory Experiment to Understand Humin Formation, Catalysis, and Green Chemistry	[218]
S157	Płotka-Wasylka, J.; Kurowska-Susdorf, A.; Sajid, M.; de la Guardia, M.; Namieśnik, J.; Tobiszewski, M.	2018	*ChemSusChem*	Green Chemistry in Higher Education: State of the Art, Challenges, and Future Trends	[52]
S158	Pohl, N.L.B.; Streff, J.M.; Brokman, S.	2012	*Journal of Chemical Education*	Evaluating sustainability: Soap versus biodiesel production from plant oils	[219]
S159	Priest, M.A.; Padgett, L.W.; Padgett, C.W.	2011	*Journal of Chemical Education*	Demonstrating the temperature dependence of density via construction of a Galilean thermometer	[220]
S160	Purcell, S.C.; Pande, P.; Lin, Y.; Rivera, E.J.; Latisha, P.U.; Smallwood, L.M.; Kerstiens, G.A.; Armstrong, L.B.; Robak, M.T.; Baranger, A.M.; Douskey, M.C.	2016	*Journal of Chemical Education*	Extraction and Antibacterial Properties of Thyme Leaf Extracts: Authentic Practice of Green Chemistry	[221]
S161	Raghuwanshi, V.S.; Wendt, R.; O'Neill, M.; Ochmann, M.; Som, T.; Fenger, R.; Mohrmann, M.; Hoell, A.; Rademann, K.	2017	*Journal of Chemical Education*	Bringing Catalysis with Gold Nanoparticles in Green Solvents to Graduate Level Students	[222]
S162	Rajapaksha, S.M.; Samarasekara, D.; Brown, J.C.; Howard, L.; Gerken, K.; Archer, T.; Lathan, P.; Mlsna, T.; Mlsna, D.	2018	*Journal of Chemical Education*	Determination of Xylitol in Sugar-Free Gum by GC-MS with Direct Aqueous Injection: A Laboratory Experiment for Chemistry Students	[223]
S163	Rajchakit, U.; Limpanuparb, T.	2016	*Journal of Chemical Education*	Greening the Traffic Light: Air Oxidation of Vitamin C Catalyzed by Indicators	[224]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S164	Rattanakit, P.; Maungchang, R.	2019	*Journal of Chemical Education*	Determining Iron(III) Concentration in a Green Chemistry Experiment Using *Phyllanthus emblica* (Indian Gooseberry) Extract and Spectrophotometry	[225]
S165	Reed, S.M.; Hutchison, J.E.	2000	*Journal of Chemical Education*	Green Chemistry in the Organic Teaching Laboratory: An Environmentally Benign Synthesis of Adipic Acid	[67]
S166	Reilly, M.K., King, R.P., Wagner, A.J. and King, S.M.	2014	*Journal of Chemical Education*	Microwave-Assisted Esterification: A Discovery-Based Microscale Laboratory Experiment	[226]
S167	Ribeiro, M.G.T.C.; MacHado, A.A.S.C.	2013	*Journal of Chemical Education*	Holistic metrics for assessment of the greenness of chemical reactions in the context of chemical education	[100]
S168	Ribeiro, M.G.T.C.; Machado, A.A.S.C.	2013	*Green Chemistry Letters and Reviews*	Greenness of chemical reactions—limitations of mass metrics	[227]
S169	Ribeiro, M.G.T.C.; Costa, D.A.; Machado, A.A.S.C.	2010	*Green Chemistry Letters and Reviews*	"Green Star": A holistic green chemistry metric for evaluation of teaching laboratory experiments	[38]
S170	Rosatella, A.A.; Afonso, C.A.M.; Branco, L.C.	2010	*Journal of Chemical Education*	Oxidation of cyclohexene to trans-1,2-cyclohexanediol promoted by p-toluenesulfonic acid without organic solvents	[228]
S171	Rubner, I.; Berry, A.J.; Grofe, T.; Oetken, M.	2019	*Journal of Chemical Education*	Educational Modules on the Power-to-Gas Concept Demonstrate a Path to Renewable Energy Futures	[229]
S172	Salman Ashraf S.; Rauf, M.A.; Abdullah, F.H.	2012	*Research in Science and Technological Education*	A hands-on approach to teaching environmental awareness and pollutant remediation to undergraduate chemistry students	[230]
S173	Samet, C.; Valiyaveettil, S.	2018	*Journal of Chemical Education*	Fruit and Vegetable Peels as Efficient Renewable Adsorbents for Removal of Pollutants from Water: A Research Experience for General Chemistry Students	[231]
S174	Sampaio, C.I.; Sousa, L.F.; Dias, A.M.	2020	*Journal of Chemical Education*	Separation of Anthocyaninic and Nonanthocyaninic Flavonoids by Liquid-Liquid Extraction Based on Their Acid-Base Properties: A Green Chemistry Approach	[232]
S175	Santandrea, J.; Kairouz, V.; Collins, S.K.	2018	*Journal of Chemical Education*	Continuous Flow Science in an Undergraduate Teaching Laboratory: Photocatalytic Thiol−Ene Reaction Using Visible Light	[233]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S176	Schaber, P.M.; Larkin, J.E.; Pines, H.A.; Berchou, K.; Wierchowski, E.; Marconi, A.; Suriani, A.	2012	*Journal of Chemical Education*	Supercritical fluid extraction versus traditional solvent extraction of caffeine from tea leaves: A laboratory-based case study for an organic chemistry course	[234]
S177	Schneiderman, D.K.; Gilmer, C.; Wentzel, M.T.; Martello, M.T.; Kubo, T.; Wissinger, J.E.	2014	*Journal of Chemical Education*	Sustainable polymers in the organic chemistry laboratory: Synthesis and characterization of a renewable polymer from δ-decalactone and L-lactide	[235]
S178	Serafin, M.; Priest, O.P.	2015	*Journal of Chemical Education*	Identifying Passerini products using a green, guided-inquiry, collaborative approach combined with spectroscopic lab techniques	[236]
S179	Sharma, R.K., Yadav, S., Gupta, R. and Arora, G.	2019	*Journal of Chemical Education*	Synthesis of Magnetic Nanoparticles Using Potato Extract for Dye Degradation: A Green Chemistry Experiment	[237]
S180	Sharma, R.K.; Gulati, S.; Mehta, S.	2012	*Journal of Chemical Education*	Preparation of gold nanoparticles using tea: A green chemistry experiment	[41]
S181	Sharma, R.K.; Sharma, C.; Sidhwani, I.T.	2011	*Journal of Chemical Education*	Solventless and one-pot synthesis of Cu(II) phthalocyanine complex: A green chemistry experiment	[238]
S182	Shell, T.A.; Shell, J.R.; Poole, K.A.; Guetzloff, T.F.	2011	*Journal of Chemical Education*	Microwave-assisted synthesis of N-phenylsuccinimide	[239]
S183	Shimizu, E.A.; Cory, B.; Hoang, J.; Castro, G.G.; Jung, M.E.; Vosburg, D.A.	2019	*Journal of Chemical Education*	Aqueous Dearomatization/Diels-Alder Cascade to a Grandifloracin Precursor	[240]
S184	Silveira, G.; Ikegaki, M.; Schneedorf, J.M.	2017	*Green Chemistry Letters and Reviews*	A low-cost yeast-based biofuel cell: An educational green approach	[241]
S185	Silverman, J.R.; Hudson, R.	2020	*Journal of Chemical Education*	Evaluating Feedstocks, Processes, and Products in the Teaching Laboratory: A Framework for Students to Use Metrics to Design Greener Chemistry Experiments	[54]
S186	Silverman, J.R.	2016	*Journal of Chemical Education*	Biobased Organic Chemistry Laboratories as Sustainable Experiment Alternatives	[242]
S187	Simeonov, S.P.; Afonso, C.A.M.	2013	*Journal of Chemical Education*	Batch and flow synthesis of 5-hydroxymethylfurfural (HMF) from fructose as a bioplatform intermediate: An experiment for the organic or analytical laboratory	[243]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S188	Sims, P.A.; Branscum, K.M.; Kao, L.; Keaveny, V.R.	2010	*Journal of Chemical Education*	An inexpensive, relatively green, and rapid method to purify genomic DNA from *Escherichia coli*: An experiment for the undergraduate biochemistry laboratory	[244]
S189	Smith, M.K.; Angle, S.R.; Northrop, B.H.	2015	*Journal of Chemical Education*	Preparation and analysis of cyclodextrin-based metal-organic frameworks: Laboratory experiments adaptable for high school through advanced undergraduate students	[245]
S190	Soares, P.; Fernandes, C.; Chavarria, D.; Borges, F.	2015	*Journal of Chemical Education*	Microwave-assisted synthesis of 5-phenyl-2-hydroxyacetophenone derivatives by a green Suzuki coupling reaction	[246]
S191	Sobral, A.J.F.N.	2006	*Journal of Chemical Education*	Synthesis of meso-diethyl-2,2′-dipyrromethane in water. An experiment in green organic chemistry	[247]
S192	Solomon, S.D.; Rutkowsky, S.A.; Mahon, M.L.; Halpern, E.M.	2011	*Journal of Chemical Education*	Synthesis of copper pigments, malachite and verdigris: Making tempera paint	[248]
S193	Stacey, J.M.; Dicks, A.P.; Goodwin, A.A.; Rush, B.M.; Nigam, M.	2013	*Journal of Chemical Education*	Green carbonyl condensation reactions demonstrating solvent and organocatalyst recyclability	[249]
S194	Steele, J.H.; Bozor, M.X.; Boyce, G.R.	2020	*Journal of Chemical Education*	Transmutation of Scent: An Evaluation of the Synthesis of Methyl Cinnamate, a Commercial Fragrance, via a Fischer Esterification for the Second-Year Organic Laboratory	[250]
S195	Strachan, J.; Barnett, C.; Maschmeyer, T.; Masters, A.F.; Motion, A; Yuen, A.K.L.	2020	*Journal of Chemical Education*	Nanoparticles for Undergraduates: Creation, Characterization, and Catalysis	[251]
S196	Sues, P.E.; Cai, K.; McIntosh, D.F.; Morris, R.H.	2015	*Journal of Chemical Education*	Template effect and ligand substitution methods for the synthesis of iron catalysts: A two-part experiment for inorganic chemistry	[252]
S197	Summerton, L.; Hurst, G.A.; Clark, J.H.	2018	*Current Opinion in Green and Sustainable Chemistry*	Facilitating active learning within green chemistry	[34]
S198	Sutheimer, S.; Caster, J.M.; Smith, S.H.	2015	*Journal of Chemical Education*	Green Soap: An Extraction and Saponification of Avocado Oil	[253]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S199	Tallmadge, W.; Homan, M.; Ruth, C.; Bilek, G.	2004	*Chemical Health and Safety*	A local pollution prevention group collaborates with a high school intermediate unit bringing the benefits of microscale chemistry to high school chemistry labs in the Lake Erie watershed	[85]
S200	Tamburini, F.; Kelly, T.; Weerapana, E.; Byers, J.A.	2014	*Journal of Chemical Education*	Paper to Plastics: An Interdisciplinary Summer Outreach Project in Sustainability	[22]
S201	Teixeira, J.M.; Byers, J.N.; Perez, M.G.; Holman, R.W.	2010	*Journal of Chemical Education*	The question-driven laboratory exercise: A new pedagogy applied to a green modification of grignard reagent formation and reaction	[98]
S202	Tian, J.; Yan, L.; Sang, A.; Yuan, H.; Zheng, B.; Xiao, D.	2014	*Journal of Chemical Education*	Microwave-Assisted Synthesis of Red-Light Emitting Au Nanoclusters with the Use of Egg White	[254]
S203	Timmer, B.J.J.; Schaufelberger, F.; Hammarberg, D.; Franzén, J.; Ramström, O.; Dinér, P.	2018	*Journal of Chemical Education*	Simple and Effective Integration of Green Chemistry and Sustainability Education into an Existing Organic Chemistry Course	[255]
S204	Touaibia, M.; Selka, A.; Levesque, N.A.; St-Onge, P.A.	2020	*Journal of Chemical Education*	Green hydrogenation: Solvent-free hydrogenation of pinenes for an undergraduate organic chemistry laboratory	[256]
S205	Vargas, B.P.; Rosa, C.H.; Rosa, D.D.S.; Rosa, G.R.	2016	*Educacion Quimica*	"Green" Suzuki-Miyaura cross-coupling: An exciting mini-project for chemistry undergraduate students	[257]
S206	Verdía. P.; Santamarta, F.; Tojo, E.	2017	*Journal of Chemical Education*	Synthesis of (3-Methoxycarbonyl)coumarin in an Ionic Liquid: An Advanced Undergraduate Project for Green Chemistry	[258]
S207	Villalba, M.M.; Leslie, R.; Davis, J.; Smith, R.B.	2011	*Journal of Science Education*	Designer experiments to assist in the teaching of NMR spectroscopy. A spectroscopic experiment in green chemistry	[259]
S208	Villanueva, O.; Zimmermann, K.	2020	*Journal of Chemical Education*	Transitioning an Upper-Level, Integrated Laboratory Course to Remote and Online Instruction during the COVID-19 Pandemic	[18]
S209	Virot, M.; Tomao, V.; Ginies, C.; Chemat, F.	2008	*Chromatographia*	Total lipid extraction of food using d-limonene as an alternative to n-hexane	[260]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S210	Vogelzang, J.; Admiraal, W.F.; Van Driel, J.H.	2020	*Chemistry Education Research and Practice*	Effects of Scrum methodology on students' critical scientific literacy: the case of Green Chemistry	[261]
S211	Von Dollen, J.; Oliva, S.; Max, S.; Esbenshade, J.	2018	*Journal of Chemical Education*	Recovery of Silver Nitrate from Silver Chloride Waste	[262]
S212	Wagner, E.P.; Koehle, M.A.; Moyle, T.M.; Lambert, P.D.	2010	*Journal of Chemical Education*	How green is your fuel? Creation and comparison of automotive biofuels	[263]
S213	Wang, X.; Chrzanowski, M.; Liu, Y.	2020	*Journal of Chemical Education*	Ultrasonic-Assisted Transesterification: A Green Miniscale Organic Laboratory Experiment	[264]
S214	Wang, Y.; Zhang, M.; Hu, Y.	2010	*Journal of Chemical Education*	Foam fractionation of lycopene: An undergraduate chemistry experiment	[265]
S215	Wardencki, W.; Curyło, J.; Namieśnik, J.	2005	*Polish Journal of Environmental Studies*	Green chemistry—Current and future issues	[53]
S216	Weires. N.A.; Johnston, A.; Warner, D.L.; McCormick, M.M.; Hammond, K.; McDougal, O.M.	2013	*Journal of Chemical Education*	Recycling of Waste Acetone by Fractional Distillation	[266]
S217	Williamson, C.L.; Maly, K.E.; Macneil, S.L.	2013	*Journal of Chemical Education*	Synthesis of imidazolium room-temperature ionic liquids: A follow-up to the procedure of Dzyuba, Kollar, and Sabnis	[267]
S218	Winter, R.T.; Van Beek, H.L.; Fraaije, M.W.	2012	*Journal of Chemical Education*	The nose knows: Biotechnological production of vanillin	[268]
S219	Wixtrom, A.; Buhler, J.; Abdel-Fattah, T.	2014	*Journal of Chemical Education*	Mechanochemical Synthesis of Two Polymorphs of the Tetrathiafulvalene-Chloranil Charge Transfer Salt: An Experiment for Organic Chemistry	[269]
S220	Worley, B.; Villa, E.M.; Gunn, J.M.; Mattson, B.	2019	*Journal of Chemical Education*	Visualizing Dissolution, Ion Mobility, and Precipitation through a Low-Cost, Rapid-Reaction Activity Introducing Microscale Precipitation Chemistry	[270]
S221	Wu, K.; Yu, L.; Ding, J.	2020	*Journal of Chemical Education*	Synthesis of PCL–PEG–PCL Triblock Copolymer via Organocatalytic Ring-Opening Polymerization and Its Application as an Injectable Hydrogel—An Interdisciplinary Learning Trial	[271]
S222	Wu, N.; Kubo, T.; Sekoni, K.N.; Hall, A.O.; Phadke, S.; Zurcher, D.M.; Wallace, R.L.; Kothari, D.B.; McNeil, A.J.	2019	*Journal of Chemical Education*	Student-Designed Green Chemistry Experiment for a Large-Enrollment, Introductory Organic Laboratory Course	[272]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
S223	Xie, Y.; Liu, X.; Tao, M.	2016	*Journal of Chemical Education*	Synthesizing Substituted 2-Amino-2-chromenes Catalyzed by Tertiaryamine-Functionalized Polyacrylonitrile Fiber for Students to Investigate Multicomponent Reactions and Heterogeneous Catalysis	[273]
S224	Yadav, U.; Mande, H.; Ghalsasi, P.	2012	*Journal of Chemical Education*	Nitration of phenols using $Cu(NO_3)_2$: Green chemistry laboratory experiment	[40]
S225	Zhou, H.; Zhan, W.; Wang, L.; Guo, L.; Liu, Y.	2018	*Journal of Chemical Education*	Making Sustainable Biofuels and Sunscreen from Corncobs to Introduce Students to Integrated Biorefinery Concepts and Techniques	[274]
S226	Zuin, V.G.; Segatto, M.L.; Zandonai, D.P.; Grosseli, G.M.; Stahl, A.; Zanotti, K.; Andrade, R.S.	2019	*Journal of Chemical Education*	Integrating Green and Sustainable Chemistry into Undergraduate Teaching Laboratories: Closing and Assessing the Loop on the Basis of a Citrus Biorefinery Approach for the Biocircular Economy in Brazil	[86]
S227	Bumbaugh, R.E.; Ott, L.S.	2020	*ACS Symposium Series*	Preparing and Testing Novel Deep Eutectic Solvents from Biodiesel Co-Product Glycerol for Use as Green Solvents in Organic Chemistry Teaching Laboratories	[275]
S228	Chateauneuf, J.E.; Nie, K.	2002	*ACS Symposium Series*	An investigation of Friedel-Crafts alkylation reactions in super- and subcritical CO_2 and under solventless reaction conditions	[276]
S229	Ferhat, M.A.; Meklati, B.Y.; Visinoni, F.; Vian, M.A.; Chemat, F.	2008	*Chimica Oggi*	Solvent free microwave extraction of essential oils Green chemistry in the teaching laboratory	[277]
S230	Kohn, C.	2019	*Physical Sciences Reviews*	The development of a bioenergy-based green chemistry curriculum for high schools	[278]
S231	Slater, C.S.; Savelski, M.J.	2011	*World Transactions on Engineering and Technology Education*	Partnerships with the pharmaceutical industry to promote sustainability	[279]
S232	Warner, M.G.; Succawa, G.L.; Hutchison, J.E.	2001	*Green Chemistry*	Solventless syntheses of mesotetraphenylporphyrin: new experiments for a greener organic chemistry laboratory curriculum	[280]
S233	Joshi, U.J.; Gokhale, K.M.; Kanitkar, A.P.	2011	*Indian Journal of Pharmaceutical Education and Research*	Green chemistry: Need of the hour	[281]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
1W	Cunningham, A.D.; Ham, E.Y.; Vosburg, D.A.	2011	*Journal of Chemical Education*	Chemoselective Reactions of Citral: Green Syntheses of Natural Perfumes for the Undergraduate Organic Laboratory	[282]
2W	Dicks, A.P.; Hent, A.; Koroluk, K.J.	2018	*Green Chemistry Letters and Reviews*	The EcoScale as a framework for undergraduate green chemistry teaching and assessment	[283]
3W	Gregor, R.W.; Goj, L.A.	2011	*Journal of Chemical Education*	Solvent-Free Synthesis of 2,2′-Dinitrobiphenyl: An Ullmann Coupling in the Introductory Organic Laboratory	[284]
4W	Lacuskova, D.; Drozdikova, A.	2017	*Chemistry-Didactics-Ecology-Metrology*	Biocatalytic Reduction of Ketones in A Secondary School Laboratory	[285]
5W	Lee, D.B.	2019	*Green Chemistry Letters and Reviews*	Re-casting traditional organic experiments into green guided-inquiry based experiments: student perceptions	[59]
6W	Palesch, J.J.; Gilles, B.C.; Chycota, J.; Haj, M.K.; Fahnhorst, G.W.; Wissinger, J.E.	2019	*Green Chemistry Letters and Reviews*	Iodination of vanillin and subsequent Suzuki-Miyaura coupling: two-step synthetic sequence teaching green chemistry principles	[286]
7W	Gabriela, M.; Ribeiro, T.C.; MacHado, A.A.S.C.	2011	*Journal of Chemical Education*	Metal-Acetylacetonate Synthesis Experiments: Which Is Greener?	[83]
8W	Rojas-Fernandez, A.G.; Aguilar-Santelises, L.; Millan, M.C.; Aguilar-Santelises, M.; Garcia-del Valle, A.	2017	*Multidisciplinary Journal for Education Social and Technological Sciences*	Teaching chemistry with sustainability	[287]
9W	Tavener, S.; Hardy J.; Hart, N.; Goddard, A.	2003	*Green chemistry*	Teaching green chemistry: from lemons to lemonade bottles	[288]
10W	Young, D.M.; Welker, J.J.C.; Doxsee, K.M.	2011	*Journal of Chemical Education*	Green Synthesis of a Fluorescent Natural Product	[289]
11W	Houri, A.; Wehbe, H.	2003	*Green Chemistry*	Towards an environmentally friendly chemistry laboratory: managing expired chemicals	[290]
1E	van Arnum, S.D.	2005	*Journal of Chemical Education*	An Approach towards Teaching Green Chemistry Fundamentals	[291]
2E	McKenzie, L.C.; Huffman, L.M.; Hutchison, J.E.; Rogers, C.E.; Goodwin, T.E.; Spessard, G.O.	2009	*Journal of Chemical Education*	Greener "Solutions" for the Organic Chemistry Teaching Lab: Exploring the Advantages of Alternative Reaction Media	[292]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
3E	Dintzner, M.R.; Wucka, P.R.; Lyons, T.W.	2006	*Journal of Chemical Education*	Microwave-Assisted Synthesis of a Natural Insecticide on Basic Montmorillonite K10 Clay. Green Chemistry in the Undergraduate Organic Laboratory	[293]
4E	Stark, A.; Ott, D.; Kralisch, D.; Kreisel, G.; Ondruschka, B.	2010	*Journal of Chemical Education*	Ionic Liquids and Green Chemistry: A Lab Experiment	[294]
5E	Ravia, S.; Gamenara, D.; Schapiro, V.; Bellomo, A.; Adum, J.; Seoane, G.; Gonzalez, D.	2006	*Journal of Chemical Education*	Enantioselective Reduction by Crude Plant Parts: Reduction of Benzofuran-2-yl Methyl Ketone with Carrot ("*Daucus carota*") Bits	[295]
6E	Ribeiro, M.G.T.C.; Yunes, S.F.; Machado, A.A.S.C.	2014	*Journal of Chemical Education*	Assessing the Greenness of Chemical Reactions in the Laboratory Using Updated Holistic Graphic Metrics Based on the Globally Harmonized System of Classification and Labelling of Chemicals	[296]
7E	Armenta, S.; de la Guardia, M.	2011	*Journal of Chemical Education*	Determination of Mercury in Milk by Cold Vapor Atomic Fluorescence: A Green Analytical Chemistry Laboratory Experiment	[297]
8E	Sauvage, X.; Delaude, L.	2008	*Journal of Chemical Education*	The Synthesis of "N"-Benzyl-2-Azanorbornene via Aqueous Hetero Diels-Alder Reaction: An Undergraduate Project in Organic Synthesis and Structural Analysis	[298]
9E	Hooper, M.M.; DeBoef, B.	2009	*Journal of Chemical Education*	A Green Multicomponent Reaction for the Organic Chemistry Laboratory: The Aqueous Passerini Reaction	[299]
10E	Phonchaiya, S.; Panijpan, B.; Rajviroongit, S.; Wright, T.; Blanchfield, J.T.	2009	*Journal of Chemical Education*	A Facile Solvent-Free Cannizzaro Reaction: An Instructional Model for Introductory Organic Chemistry Laboratory	[300]
11E	Ballard, C.E.	2010	*Journal of Chemical Education*	pH-Controlled Oxidation of an Aromatic Ketone: Structural Elucidation of the Products of Two Green Chemical Reactions	[301]
12E	Tundo, P.; Rosamilia, A.E.; Arico, F.	2010	*Journal of Chemical Education*	Methylation of 2-Naphthol Using Dimethyl Carbonate under Continuous-Flow Gas-Phase Conditions	[302]
13E	Akers, Stephen M.; Conkle, Jeremy L.; Thomas, Stephanie N.; Rider, Keith B.	2006	*Journal of Chemical Education*	Determination of the Heat of Combustion of Biodiesel Using Bomb Calorimetry: A Multidisciplinary Undergraduate Chemistry Experiment	[303]
14E	Lazarski, K.E.; Rich, A.A.; Mascarenhas, C.M.	2008	*Journal of Chemical Education*	A One-Pot, Asymmetric Robinson Annulation in the Organic Chemistry Majors Laboratory	[304]

Table A1. *Cont.*

Paper Code	Author(s)	Year	Name of Journal	Title	Ref.
15E	Sidhwani, I.T.; Chowdhury, S.	2008	*Journal of Chemical Education*	Greener Alternative to Qualitative Analysis for Cations without H_2S and Other Sulfur-Containing Compounds	[305]
16E	Eby, E.; Deal, S.T.	2008	*Journal of Chemical Education*	Aromatic Substitution for the Organic Chemistry Laboratory	[306]
17E	Andraos, J.; Sayed, M.	2007	*Journal of Chemical Education*	On the Use of "Green" Metrics in the Undergraduate Organic Chemistry Lecture and Lab to Assess the Mass Efficiency of Organic Reactions	[35]
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