

CHEMISTRY EDUCATION IN PORTUGAL: THE EMERGING PICTURE FROM THE PAPERS PUBLISHED IN THE *JOURNAL OF CHEMICAL EDUCATION*

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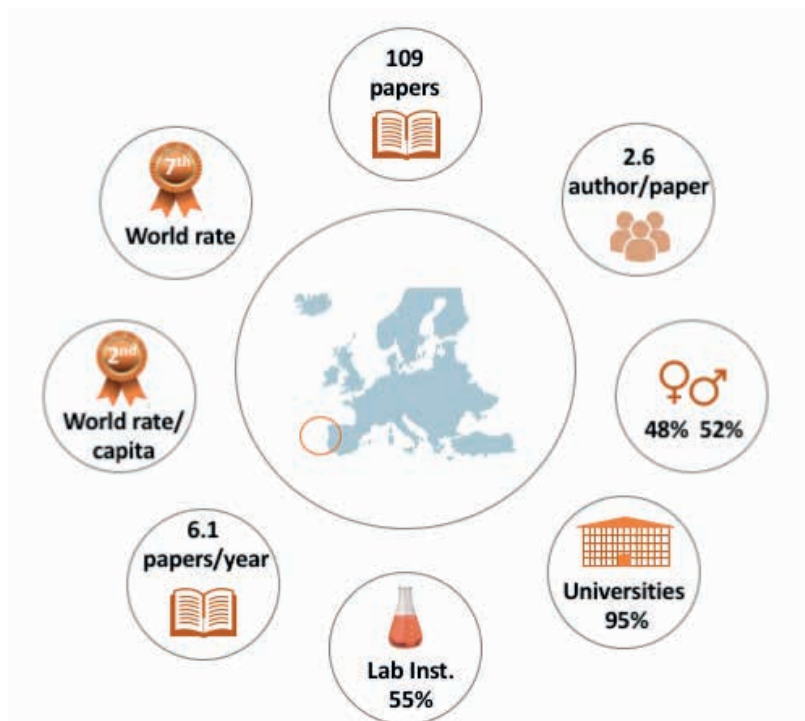
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ABSTRACT: Several challenges and opportunities face chemistry education in the 21st century with the growing role of new technologies and the globalization perspective. Manuscripts describing original and innovative strategies, either in the classroom or in the laboratory setting, are required and publishing in a top-tier journal, like the *Journal of Chemical Education* (JCE), is crucial to reach a large audience. This paper focuses on the development of chemistry education in Portugal in the 21st century through a content analysis of the papers published in JCE from 2000 to 2018 by authors with Portuguese affiliation. Regarding contributions to JCE papers by country in the same period, Portugal ranks

fourth among European countries and seventh worldwide corresponding to second in rank when considering country population (papers/million people). Papers involving laboratory experiments and other hands-on learning activities represent more than 50% of the published Portuguese authored manuscripts which covered a large audience, mainly at the undergraduate level, revealing an increased effort in laboratory instruction. Considering gender equality, the global number of men and women contributing to Portuguese affiliated publications in JCE is very similar (52% *versus* 48%, respectively) although there is only one woman in the top 5 most prolific authors. Overall, results reveal the constant and increasing effort of Portuguese affiliated authors to publish in JCE contributing to the recognition of chemistry education relevance.

KEYWORDS: General Public; Curriculum; Interdisciplinary/ Multidisciplinary; Communication/ Writing; Professional Development; Standards National/ State

GRAPHICAL ABSTRACT



INTRODUCTION

Major challenges facing chemistry education in the 21st century concern the paradigm shift from faculty-centered teaching to student-centered learning as well as implementation and/or consolidation of research-based teaching practice.^{1,2} On the other hand, new technologies are at the center of chemistry education in the new millennium, from chemistry education research resources available at the Web to chemistry applications (Chem Apps) for tablets and smartphones. These technologies go far beyond simple information delivery, being powerful tools that can provide significant enhancement of conceptual understanding in Chemistry.³ Additionally, the globalization context and the international interchange student programs brought the need for changing perspectives in the Chemistry curriculum,¹ both at the high-school and at the university level.

Dissemination of research in chemistry education plays a major role in the advance of the field.⁴⁻⁶ The main peer-reviewed journals specifically publishing in chemistry education (Table 1) are not indexed in the ISI/Web of Science (WoS), and those that are, have rather low impact factors (IF).⁷ Alternative Scopus/SCImago journal rank (SJR) indicators⁸ and other metrics like h-index^{7,8} are also low for most of them (Table 1), which may partially result from the slow pace of publication in the area.^{4,9,10} Additionally, several indexed

science education research journals, some with higher IF values, are available that also publish chemistry education research, such as *Journal of Research in Science Teaching* (USA, IF=3.179) and *International Journal of Science Education* (UK, IF=1.240).⁷ Serving the Iberoamerican community, *Educacion Quimica* (Table 1) is an alternative option and the only one listed that accepts papers written in Portuguese or Spanish apart from English.

Journal (Country)	Publisher (frequency, date)	IF ^a	SJR, h-index ^b
Australian Journal of Education in Chemistry (AUS)	Royal Australian Chemical Institute (quarterly, since 1978)	n/a	n/a
Biochemistry and Molecular Biology Education (USA)	John Wiley & Sons (bimonthly, since 1972)	0.627	0.370, h-30
Chemical Engineering Education (USA)	American Society for Engineering Education (quarterly, since 1962)	n/a	0.137, h-22
Chemistry Education Research and Practice (UK)	Royal Society of Chemistry (quarterly, since 2000)	1.941	0.631, h-31
Educación Química (MEX)	Faculty of Chemistry of the National Autonomous University of Mexico, hosted by Elsevier (quarterly, since 1989)	n/a	0.209, h-6
Education for Chemical Engineers (UK)	Institution of Chemical Engineers, hosted by Elsevier (quarterly, since 2006)	n/a	0.273, h-14
Education in Chemistry (UK)	Royal Society of Chemistry (bimonthly, since 1964)	n/a	0.106, h-5
Journal of Chemical Education (USA)	American Chemical Society (monthly, since 1924)	1.419	0.466, h-65
The Chemical Educator (USA)	chemeducator.org; online only (bimonthly, since 1996)	n/a	n/a
World Journal of Chemical Education (USA)	Science and Education Publishing (bimonthly, since 2013)	n/a	n/a

^aIF, 2016 impact factor (2-Year) according to 2017 Journal Citation Reports.⁷ ^bSJR, SCImago journal ranking, and h-index according to 2017 SCImago journal rankings;⁸ n/a, not available.

Table 1. Major Chemistry Education Journals (in Alphabetical Order) and Journal Metrics

Among the chemistry education journals, *Journal of Chemical Education* (JCE) and *Chemistry Education Research and Practice* are considered the top-tiered journals that primarily serve the chemistry education community.¹¹ Additionally, JCE publishes laboratory experiments and classroom activities that although not formerly considered chemistry education research, provide valuable tools for teachers and chemical educators.^{12,13} Although Portuguese authors writing chemistry education papers in their native language often publish in *Boletim da Sociedade Portuguesa de Química*, a quarterly magazine of the Portuguese Chemical Society, publishing in an internationally recognized top-tier journal like JCE is an appealing challenge and can also add a contribution in terms of academic progression.^{4,9} Requirements for successful publication in JCE mainly reside in “scholarship, novelty, pedagogy, and presentation” according to JCE authors guidelines.¹⁴

This paper concerns the development of chemistry education in Portugal in the 21st century through a content analysis of the papers published in JCE from 2000 to 2018 by authors with Portuguese affiliation.

METHODS

A refined search of the manuscripts published in JCE (*Publication Name*) between 2000 and 2018 (*Timespan*) was performed in the WoS database (Clarivate Analytics).¹⁵ Several filters were selected, namely *Countries/Regions*, *Publication Years*, *Document Types*, *Organizations-Enhanced*, *Authors* and again *Countries/Regions* to obtain Portuguese collaborations with foreign institutions.

A complementary search was conducted in the American Chemical Society (ACS) publications webpage¹⁶ using the advanced search option with the keyword *Portugal* in the abstract and restricting the search to JCE (*Content Type*), selecting publications between 2000 and 2018 (*Publication Date*). All papers by authors with Portuguese affiliation published between 2000 and 2018 in JCE, up to April 2018, were downloaded and analyzed concerning the authors' institution(s), number of authors per paper, number of papers published per year, type of manuscript, and JCE keywords regarding audience, domain, pedagogy and topics. For JCE keywords, a paper may be classified under more than one category and the frequency of occurrences was summed. A total of 109 papers were analyzed, information was tabulated and checked independently.

RESULTS AND DISCUSSION

Among the 7545 papers published in JCE between 2000 and 2018, the major part is from the United States of America (USA), corresponding to 5055 (67.0%) papers, according to the WoS database¹⁵. Papers from authors with Portuguese affiliation in the same period amount to 109 (1.4%), representing 8.8% of the European papers published in JCE with Portugal ranking 4th in the European countries with more publications in JCE, and ranking 7th worldwide (Figure 1).



Figure 1. Major countries contributing to papers in JCE between 2000–2018.¹⁵

Portugal is a small country in southern Europe and when comparing the number of publications in JCE in this period regarding the population density of countries (e.g. papers/million people in 2017) Portugal rises to 2nd place in the world ranking, after the USA that remains first.¹⁷ Portuguese authors seem to consider JCE an appealing and high visibility journal regardless of impact factor and have continued to dedicate part of their efforts in producing chemical education work to share with the educational and scientific community. This is rather interesting considering the global importance that impact factors have gained in the last years. Moreover, Portuguese authors published regularly in JCE since 2000 (Figure 2), contributing with a mean number of 6.1 papers per year. According to the number of Portuguese authored papers published in JCE since 2000, a slight increase has been observed from the first decade (50 papers) to the second decade (59 papers since 2010) which is likely to rise up to 2020.

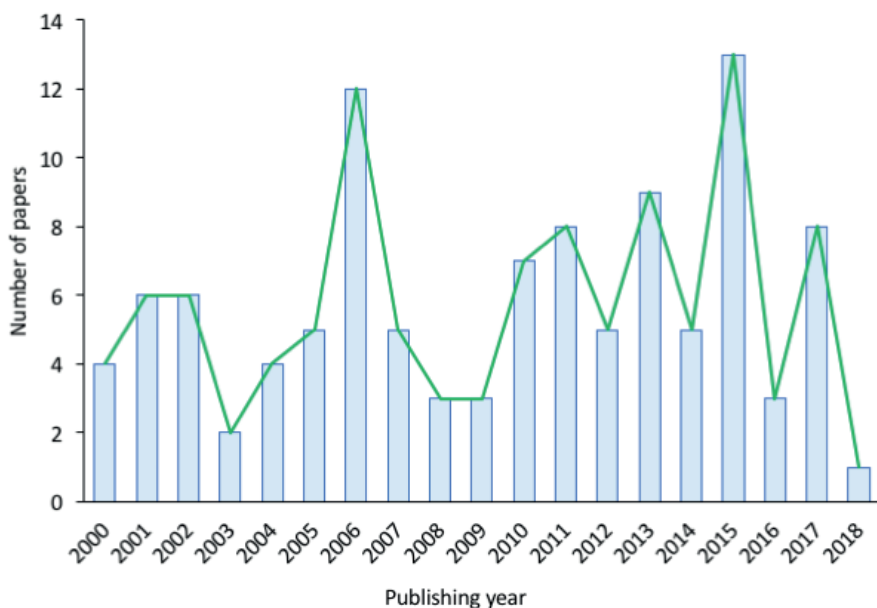


Figure 2. Portuguese authored papers published per year in JCE from 2000 to 2018.

The scope of most of the published work of Portuguese affiliated authors corresponds to experimental chemistry activities which is certainly one of the main interesting ways to learn chemistry. Actually, the present decade showed a huge increase in the number of papers reporting chemistry laboratory activities. From the 31 papers describing laboratory experiments, 29 were published between 2010 and 2018, representing more than 47% of the published Portuguese authored papers in that period. Furthermore, in 60 of the 109 published papers, corresponding to 55% of publications, hands-on learning/manipulatives appeared in the JCE keyword search as their main goal. This is hardly a surprise since experimentation is at the heart of Chemistry and chemistry education. The chemistry laboratory is a unique learning environment that contributes to enhancing cognitive growth and promotes positive attitudes such as team work, cooperation, and communication skills.¹⁸ Engaging students in laboratory as well as classroom activities linked to real-life and that lead to dissemination of results (papers, posters, oral presentations, etc.) enhances students' motivation and can contribute to improvement of the learning process.^{19,20} Furthermore, an effort has been made to introduce modern instrumentation and new methodologies in the educational laboratory setting.^{21,22}

The papers by Portuguese affiliated authors covered a large audience, mainly at the undergraduate level, with 47 papers (43%), 28 papers (26%) and 21 papers (19%) intended to upper-division, second-year, and first-year undergraduate students, respectively. Another

17 papers (16%) were dedicated to high school/introductory chemistry. Most papers focused mainly in laboratory instruction and most were in the Physical Chemistry, Analytical Chemistry or Organic Chemistry areas, although other domains were also covered (Table 2). On the other hand, only one paper concerned Inorganic Chemistry. A huge number of topics were covered by the 109 papers, with green chemistry (11%) being the most frequent one, followed by synthesis (8%) and chemical equilibrium (7%).

Domain	Papers	% of 109
Laboratory Instruction	39	35.8
Physical Chemistry	23	21.1
Analytical Chemistry	20	18.3
Organic Chemistry	18	16.5
Interdisciplinary/Multidisciplinary	13	11.9
Biochemistry	10	9.2
Chemical Engineering	6	5.5
History/Philosophy	6	5.5

Table 2. Main Domains of Portuguese Authored Papers Published in JCE (2000–2018)

Considering the Portuguese educational program in Chemistry, it is in universities and polytechnic institutes that experimental settings for chemistry learning are more frequent. This reality is therefore in accordance with the audience covered in the 109 publications mentioned. Unfortunately, at the high school level the learning of chemistry through experimentation is generally not frequent. Thus, contributions to the Portuguese authored publications came from 22 institutions (Figure 3), including 14 universities, among them only two private ones (*Universidade Católica do Porto* and *Universidade Lusófona de Humanidades e Tecnologias*) 5 polytechnic institutes, one secondary school (*Escola Secundária de Penacova*, Coimbra) and one public hospital (*Instituto Português de Oncologia* (IPO), Porto). From those, 9 institutions contributed with only one paper.

The fact that most publications are affiliated in universities is related to the importance of experimental activities included into the learning methodologies of these institutions and also to the high and intense publishing activities of their professors and researchers.

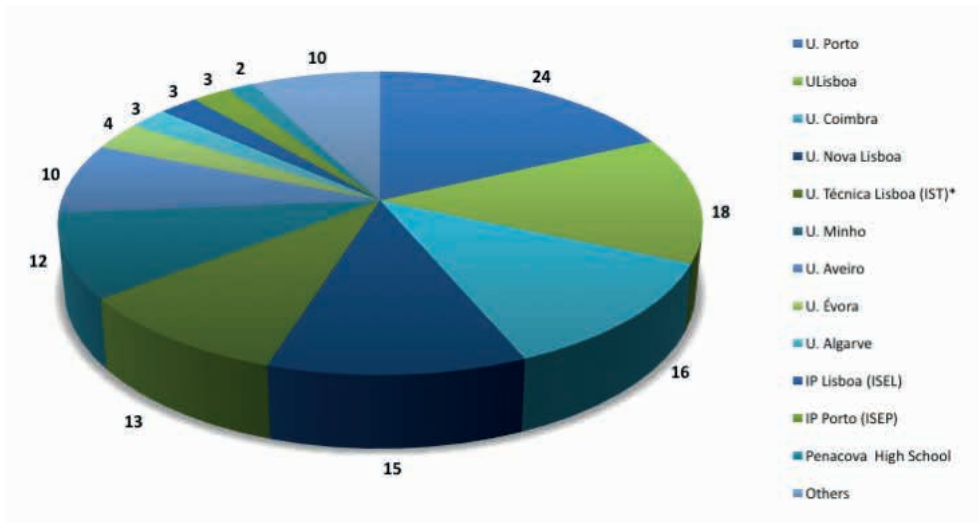


Figure 3. Portuguese authored papers published since 2000 in JCE by institution. Others represent institutions that contributed with only one paper (*U. Açores, U. Beira Interior, U. Católica Porto, U. Lusófona de Humanidades e Tecnologias, U. Trás-os-Montes e Alto Douro, Instituto Português de Oncologia do Porto* and the polytechnic institutes (IP) from Castelo Branco, Coimbra, and Setúbal). *IST, *Instituto Superior Técnico* (U. Técnica Lisboa), merged with ULisboa in July 2013. The data presented includes papers shared between different institutions.

Among the 109 publications, 95.4% of the papers came from public universities, and in 68.8% of the papers, authors were all from the same institution, which may reflect the endogamy of Portuguese universities. Only 12 papers (11%) involved international collaborations while national collaborations contributed to 22 papers (20%) from the 109 papers published, with a mean number of 2.6 authors per paper. Among the twelve papers involving international collaborations, five were with Scotland (University of St. Andrews), two with Spain (*Universidad de Valencia* and *Universidad de Extremadura*), one with England (Oxford University), one with Brazil (*Universidade Federal de Santa Catarina*), one with the United States (University of Miami), one with Sweden (Lund University) and one with France (*Conservatoire National des Arts et Métiers, Paris*).

From the 190 authors with Portuguese affiliation responsible for publications in JCE since 2000, 78.4% published only once while 15.3% published twice. The top 5 most prolific authors were João C. M. Paiva (*Universidade do Porto*) with 12 papers, Víctor M. S. Gil (*Universidade de Coimbra*) with 10 papers, Carlos A. M. Afonso (*Universidade de Lisboa*) and Michael J. Smith (*Universidade do Minho*), both with 7 papers, M. Gabriela T. C. Ribeiro and Adélio A. S. C. Machado (*Universidade do Porto*) both with 5 papers. Although there is only a female author in the top five Portuguese affiliated authors, the global number of men and women with Portuguese affiliation that have published in JCE is very similar, being of 51.6% and 48.4%, respectively. In Portugal the number of women graduating in recent years has been increasing as well as the number of women in science, technology,

engineering and mathematics (STEM) areas, a tendency that contrasts with other countries signing the Organization for Economic Co-operation and Development (OECD) convention.²³ Portuguese female share of graduate from bachelor's programs represents 60.2% while female share of graduates in science, mathematics and computing represent 56.9%, according to OECD data from 2014.²³ It is worth mentioning that only around 20% of university students worldwide enrolling in STEM areas are women.²³

Overall, it is gratifying to notice that authors from Portuguese institutions regularly publish their chemical education work in JCE since the pressure to publish scientific work in high impact factor journals is an inevitable reality and time to invest in pedagogic publications is sometimes scarce.^{5,9} Researching and writing a paper in chemical education is a major effort but it is also a rewarding investment that may potentially contribute to increase the low annual publication rate and low IF in the field,^{13,24,25} leading to a wider recognition of chemical education relevance in the academic community.

CONCLUSION

The analysis of the papers published in JCE during 2000–2018 by authors with Portuguese affiliation showed that contributions from Portugal are included in the top five and top ten European and Worldwide country ranking, respectively, regarding the total number of papers published in the same period. Hands-on learning instruction represents 55% of the publications, concerning as major domains Physical, Analytical, and Organic Chemistry, which shows a clear trend towards laboratory instruction. However, the present review is limited to JCE and further analysis of other chemistry education journals may confirm and/or identify other trends. The majority of papers involved research aiming at the undergraduate level conducted in the higher education context mainly by academics from Portuguese public universities. The top 5 most prolific authors were all academics from Portuguese public universities. Further collaborations among different institutions could add diversity of perspectives and improve representative results.

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Notes

The authors declare no competing financial interest.

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