# A Quantitative Characterization of Audience Response System Research

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## Abstract

Audience Response Systems (ARS) can be used to increase students' commitment and engagement. ARS are becoming popular at lectures, complementing traditional masterclasses and shedding light to a more profitability of the time. Several researchers studied the impact of ARS in the classroom. However, there is a lack of information about the current research landscape to identify paths towards the development of scientific research and projects in ARS field. This bibliometric study discusses a collection of bibliometric parameters on ARS literature that were calculated from data downloaded in Scopus database. A total of 2,015 publications were considered from Scopus database. Results showed that the number of publications is stable since 2010 with a noticeable decrease in 2019. The United States and the United Kingdom are the most productive countries with a total of 898 papers in the US and 179 in the UK. The most prolific author was Daniel Zingaro from the University of Toronto with a total of 10 manuscripts published. This study provides researchers who are interested in conducting research on ARS with insights on potential venues for publications and collaboration with research institutions and researchers that are more prolific in the field.

**Keywords:** Audience response systems, Bibliometric analysis, Educational technology

## 1 Introduction

Students' engagement is considered to be critical for successful learning [1-2] and a strong predictor of educational outcomes [3]. Students' engagement has become in higher education institutions a pivotal focus of attention to retain students [4-5]. According to [6], there are four approaches to understand students' engagement: (i) behavioural, which focuses on the effectiveness of teaching practice; (ii) psychological, which considers engagement as an internal individual process; (iii) socio-cultural; and (iv) holistic, which strives to draw the strands together. The aforementioned dimensions are interlinked and depend on each other, however it is difficult to examine all facets when putting the student at the center of attention [6]. Research suggests that there are various approaches to improve student engagement in high education [7-8].

Technology can be used by instructors and educators as a tool to create supportive learning environments [9-11]. Students which used Audience response systems (ARS), also known as 'clickers', reported being more confident in their abilities and spending less time preparing for the course outside of class without impacting their performance [12-13]. The use of ARS enhanced student engagement in a large classroom for both extrovert and introvert students [9]. Several studies have also established that students were very satisfied with the use of clickers in the classroom [14-16] . Literature shows that the use of such systems increases students' attendance, attention levels, participation and engagement [17]. Moreover, clicker-based technologies may be used to design curriculum to capture misconceptions that students might have about topics taught in their classrooms [18].

The benefits of ARS technology can be strengthened by combining ARS technology and mobile technology, thus improving students' grade performance and classroom experience [19]. Mobile ARS are used to allow students "answer electronically displayed multiple choice questions using a remote control device" [17].

With all these contributions demonstrating the benefit of ARS in education, researchers might wonder if this research topic is still innovative, which is the evolutionary tendency of this field, which countries, researchers and research teams publish most frequently and which journals can be the main forum for dissemination of this type of research.

A bibliometric analysis of new technology trends in education was developed in 2018 [20]. The authors assessed the scientific impact of mainstream education by using Web of Science (WoS) and Google Scholar (GS). However, ARS was not specifically dealt with. Another topic-based bibliometric study of papers published from 1999 to 2018 reported the results of analyzing relevant articles on the application of technology in classroom dialogue [21]. Four existing prominence areas of research were identified: Dialogue, Settings, Collaboration and Information communications technology. Scientific production of educational technology in the higher education stage also was analyzed in a bibliometric study using the Web of Science database [22]. Other bibliometric studies have focused on specific disciplines such as Software Engineering education [23]. To the best of our knowledge, no papers have been published that address the overall changes in the ARS literature landscape over the last decade. There is therefore a

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need to have a bibliometric analysis of publications in ARS for education to assist in their decision-making process. For this purpose, the following research question (RQ) was formulated:

**RQ**. What is the research profile of ARS for education in Scopus-indexed publications before 2020?

To answer the aforementioned RQ, this study conducts a bibliometric analysis on a total of 2,015 publications selected from Scopus with no restriction on the publication period. This study gives an overview of trends related to ARS, which may assist in promoting future research in this topic and suggest new contributions and alternatives to the traditional education approaches.

A bibliometric study provides researchers with brief information and concise data on scientific publications in a comprehensible form [24] and its results can be used to investigate the scientific outputs in a field of interest [25]. Amongst the main advantages of bibliometric studies lie neutrality and objectivity. These kinds of studies apply bibliometric approach to explore publications on a variety of aspects [26]. Outcomes of bibliometric studies can be an aid to decision-making and research management in a specific field [27].

The remainder of this article is organized as follows: the methodology used to select publications from Scopus database is presented in Materials and Methods section. Results section describes the bibliometric results. Results are discussed in Discussion section. Finally, Conclusions section presents conclusions, suggestions, future works and limitations.

## 2 Materials and Methods

Bibliometric studies aim to quantitative analyze documents in scientific communication by their bibliographic content [28]. Literature output information is provided in a brief and a comprehensible way in these manuscripts [24], collecting bibliometric parameters that expose the relevance of a particular research topic for the academic community [29]. Many research fields use bibliometric methods to discover the impact of their field, to quantify research performance of institutions and researchers, or assess the impact of a particular paper. In addition to bibliometric parameters, the visual maps are a useful tool for decision—makers who need to solve real problems of research planning and development [30].

The data employed to perform this bibliometric analysis was gathered from the Scopus database, which is one of largest digital bibliometric databases and most commonly used as a source for extracting data used in bibliometric studies [31-32]. In order to extract the publications, the following search string was built from the different terminology found in the literature related to ARS [33]. This search string was employed in the advance search at Scopus. The search string can be downloaded in https://docentis.inf.um.es/downloads/search_string.txt.

The title produces a representative sample of the field of interest based on a long tradition of research papers which show the usefulness of article titles [34]. The results were downloaded in a CSV file from the database. A set of 4 manuscripts were discarded as the year in which they were published was 2020. The search was performed on the 15th of December 2019 and a total of 2,015 publications were considered.

A sensitivity analysis was carried out on the total of publications obtained. The aim was to ensure that the terms forming the search chain were producing the expected results. To evaluate the accuracy of the publications with the topic of interest in this study, a subset of publications was selected randomly from the selected publications in Scopus. The topic of each publication was then reviewed. The Cochran's sample size formula (1) [35] has been used to establish the number of papers selected to accomplish the validation step.

$$n = \frac{NZ^2 p(1-p)}{(N-1)e^2 + Z^2 p(1-p)}. \quad \textbf{(1)}$$

Where n is the number of publications randomly selected for the analysis, N is the total number of documents considered in the study, Z is the mean value's deviation accepted for a particular level of confidence (i.e.: a level of confidence of 90% signifies Z = 1.645, 95% signifies Z = 1.96, and 99% signifies Z = 2.575), e represents the error margin, and p represents a set of results expected to be invalid.

With

N = 2015

Z = 1.96 (level of confidence 95%)

e = 0.05

p = 0.08 (expected to be low)

a sample of 107 publications were read carefully to proceed with the validation.

A total of 8 publications out of the 107 publications revised were not related to ARS. This result represents a proportion of 7.5% of invalid results (8% expected).

A set of basic tools were necessary to study the data. This CSV file was read with Microsoft Excel tool together with python's Pandas Library. This file can be found in: https://docentis.inf.um.es/downloads/ars_datas.csv.

Excel allowed to analyze the results in a quick and a high level, and to draw some of the figures exposed in the paper. On the other hand, Pandas Library made possible to automate the treatment of CSV file, extracting the data of interest to calculate each one of the parameters with python coding. The VOSviewer tool was used to represent clustered data in Section 3.

## 3 Results

This section presents the results of the bibliometric study, which are categorized in six subsections [36]: Descriptive Analysis, Author Production, Journal Productivity, Scientific Collaboration, Author Citation Analysis, and Journal Citation Analysis.

### 3.1 Descriptive Analysis

This section presents a descriptive analysis of the

following groups of the selected publications' characteristics:

- **Temporal evolution** which collects parameters such as: (i) growth of publications; (ii) annual growth rate (AGR) of the publications; (iii) compound annual growth rate (CAGR) of the publications; (iv) relative growth rate (RGR); (v) doubling time (DT); and (vi) trend analysis for the number of publications.
- **Institutions and countries** which collects parameters regarding: (i) most prolific institutions; and (ii) geographical distribution of the selected publications.
- **Language**, which collects the languages in which the selected publications were written.
- **Type of document**, which considers these bibliometric variables: (i) kind of publications; and (ii) authors' keywords in publications.

### 3.2 Temporal Evolution

**Growth of publications.** Results show that the interest of this topic stayed in the same level, varying between 108 to 168 publications as exposed in Table 1 during the last 10 years. A detailed view of Figure 1 shows that, compared to the previous year, the interest in this topic decreased in attention during 2019.

**Table 1.** Growth of publications

| Year | Number of publications | % |
|---|---|---|
| 2019 | 118 | 5.86 |
| 2018 | 166 | 8.24 |
| 2017 | 124 | 6.15 |
| 2016 | 143 | 7.10 |
| 2015 | 168 | 8.34 |
| 2014 | 153 | 7.59 |
| 2013 | 159 | 7.89 |
| 2012 | 122 | 6.05 |
| 2011 | 156 | 7.74 |
| 2010 | 130 | 6.45 |
| 2009 | 108 | 5.36 |
| 2008 | 468 | 23.23 |

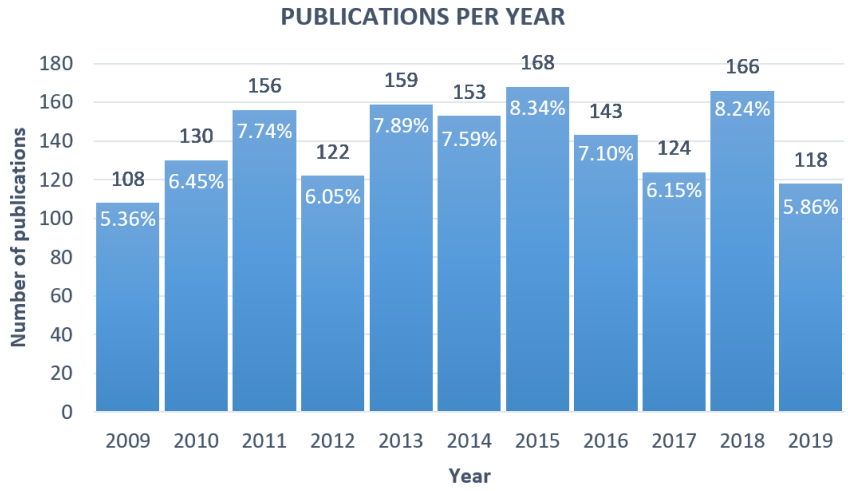



**Figure 1**. Publication's growth

***Annual Growth Rate of the publications.*** The AGR provides a comparison of the total number of publications produced in a year and the previous year. This parameter is obtained from the number of publications in Year N and the number of publications from the Year N-1 according to the following formula (2).

$$AGR(\%) = 100 * \frac{Publications\ (Year\ N) - Publications\ (Year\ N-1)}{Publications\ (Year\ N-1)}. \quad \textbf{(2)}$$

A stable trend over the years can be seen in Table 2 despite the volatile figures, between approximately -30 to 30 %, in the last decade. Negative values were attained in some of the cases (2019, 2017, 2016, 2014 and 2012). This is because fewer publications were produced compared to the previous year.

**Table 2.** Compound annual growth rate (CAGR)

| Year | Cumulative | CARG (%) |
|---|---|---|
| 2019 | 1547 | 29.35 |
| 2018 | 1429 | 27.02 |
| 2017 | 1263 | 33.66 |
| 2016 | 1139 | 34.51 |
| 2015 | 996 | 34.53 |
| 2014 | 828 | 40.17 |
| 2013 | 675 | 43.54 |
| 2012 | 516 | 61.72 |
| 2011 | 394 | 58.92 |
| 2010 | 238 | 83.08 |
| 2009 | 108 | - |

***Compound Annual Growth Rate.*** The CAGR compares the AGR parameter of different periods of time, according to (3). To calculate CAGR we considered the number of publications produced in a year, the cumulative number of publications from a year to a year of reference, and the difference in number of years. The reference year in this case was 2009.

$$CAGR(\%) = 100 * \left[\left(\frac{CumulativePublicationsYear}{PublicationsYear}\right) \wedge \left(\frac{1}{(Year - referenceYear)}\right)\right]. \quad \textbf{(3)}$$

Figure 2 and Table 3 show the CAGR parameter's results. The year 2013 was highlighted by a significant decrease in the CAGR, which has fallen since then from 43.54% to 29.35%. The stable trend over the last decade in the number of publications per year, which is between 100 and 150, provides an established upward trend in the growth of the cumulative number of publications per year.

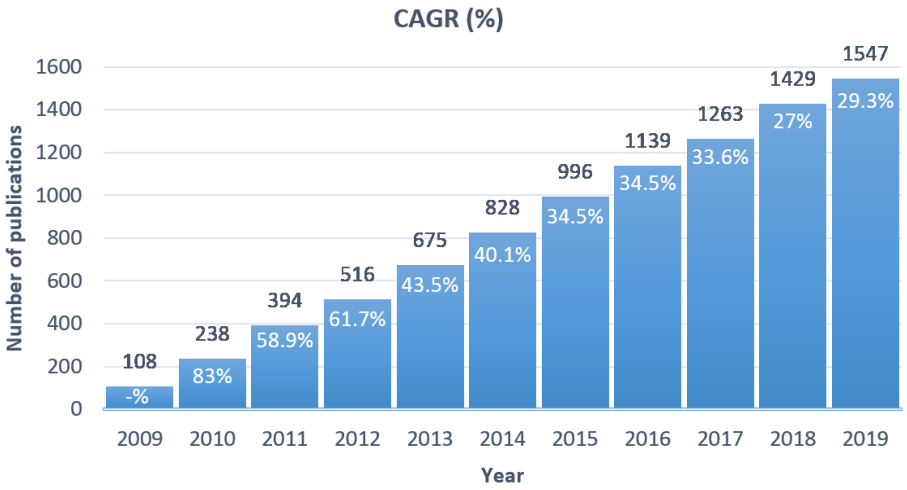



**Figure 2**. Compound annual growth rate (CAGR)

**Relative Growth Rate and Doubling Time Factor.** The RGR shows hikes in the trend related to the number of publications per unit of time. To calculate RGR, we employed naperian logarithms in the accumulated number of publications of a Year N ($W_2$) and the previous Year N-1 ($W_1$). The time frame of one year between $W_2$ and $W_1$ was also considered (4). This parameter made possible to get straightaway the DT factor, which in this case is the number of years needed to double publications accumulated in a given year (8).

$$RGR = \frac{lnW_2 - lnW_1}{Year - previousYear}. \quad \textbf{(4)}$$

$$W_2 = 2 \cdot W_1. \quad \textbf{(5)}$$

$$DT = Year_2 - Year_1. \quad \textbf{(6)}$$

$$RGR = \frac{ln(2 \cdot W_1) - lnW_1}{DT}. \quad \textbf{(7)}$$

$$DT = \frac{ln(2)}{RGR}. \quad \textbf{(8)}$$

Table 3 shows that DT has increased almost each year. In 2010, the parameter had a value of less than 1, whereas in last year it is around 9. Figure 3 shows that RGR has decreased in the last years, starting at 0.79 in 2010 while in 2019 it was 0.08.

**Table 3.** Relative growth rate (RGR) ad doubling time (DT)

| Year | $\ln W_1$ | $\ln W_2$ | RGR | DT (years) |
|---|---|---|---|---|
| 2019 | 7.26 | 7.34 | 0.08 | 8.73 |
| 2018 | 7.14 | 7.26 | 0.12 | 5.61 |
| 2017 | 7.04 | 7.14 | 0.10 | 6.71 |
| 2016 | 6.90 | 7.04 | 0.13 | 5.17 |
| 2015 | 6.72 | 6.90 | 0.18 | 3.75 |
| 2014 | 6.51 | 6.72 | 0.20 | 3.39 |
| 2013 | 6.25 | 6.51 | 0.27 | 2.58 |
| 2012 | 5.98 | 6.25 | 0.27 | 2.57 |
| 2011 | 5.47 | 5.98 | 0.50 | 1.37 |
| 2010 | 4.68 | 5.47 | 0.79 | 0.88 |

**Trend analysis for the number of publications.** A trend analysis was carried out to find out the estimated number of publications in the future. The least squares method was employed to this end, adjusting a linear function (9) to the data collected from 2009 to 2018.

$$Y = b \cdot X + a \Rightarrow Y = \frac{547}{330} \cdot X + \frac{1429}{10}. \quad \textbf{(9)}$$

The coefficients a and b of the previous formula (9) were calculated minimizing the following function (10).

$$F(a,b) = \sum (Y - a - b \cdot X). \quad \textbf{(10)}$$

To minimize this function (10), the system of equations formed by (11) and (12) was solved. In these equations is the

number of years in which the publications were considered to calculate the tendency, is the real number of publications in each year and $X$ is the year.

$$\sum Y = N \cdot a + b \cdot \sum X. \quad \textbf{(11)}$$

$$\sum Y \cdot X = a \cdot \sum X + b \cdot \sum X^2. \quad \textbf{(12)}$$

To solve the system of equations, the ordered at the origin was the first parameter calculated, which is the coefficient in equation (9). To attain easily this parameter, the values were centered on the -axis. That is to say that all known values are associated with values that when they are all added up, the result is zero (13).

$$\sum_{n=2009}^{2018} X_n = 0. \quad \textbf{(13)}$$

Resulting in (14) (see Table 5):

$$a = \frac{\Sigma Y}{N} = \frac{1429}{10}. \quad \textbf{(14)}$$

To attain the $b$ coefficient, the summations of the values in Table 5 were used:

$$b = \frac{\Sigma Y \cdot X}{\Sigma X^2} = \frac{547}{330}. \quad \textbf{(15)}$$

Table 4 shows that the increment in the number of publications per year will be of approximately 3 in the coming 4 years. Moreover, Figure 4 presents the number of publications of the lineal model versus the known number of publications of the considered years to obtain the tendency. The Difference column in Table 5 depicts the increment in the number of publications between two consecutive years, which was around 3. From 2010 to 2018 this difference has been calculated by using the real number of publications from the database (column Y). Nevertheless, from 2019 the difference can only be calculated by using the estimated values (column f(x)).

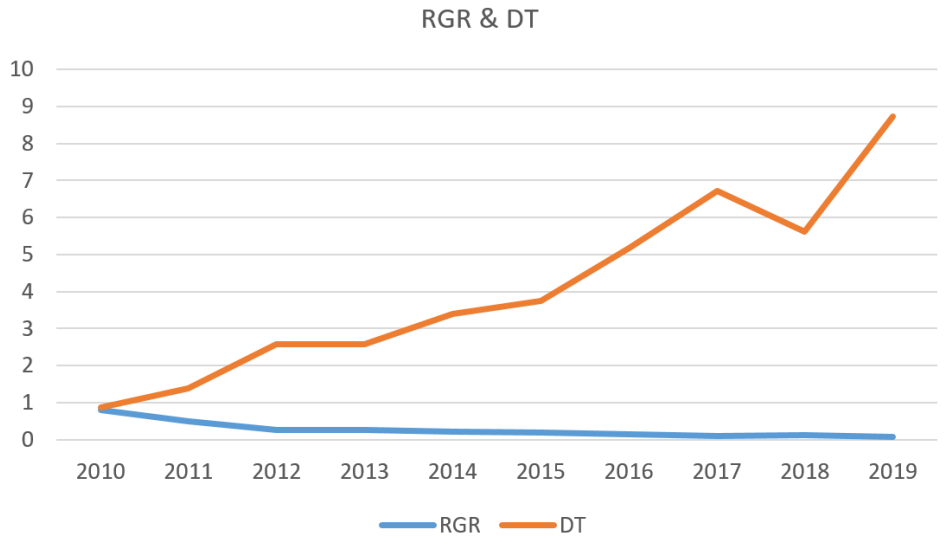



**Figure 3**. Relative growth rate (RGR) and Doubling time (DT)

**Table 4.** Tendency analysis graph of the number of publications per year

| Year | Y | X | Y·X | X | f(X) | Difference |
|---|---|---|---|---|---|---|
| 2023 | | 19 | | | 174.39 | 3.31 |
| 2022 | | 17 | | | 171.07 | 3.31 |
| 2021 | | 15 | | | 167.76 | 3.31 |
| 2020 | | 13 | | | 164.44 | 3.31 |
| 2019 | 118 | 11 | | | 161.13 | - |
| **2018** | 166 | 9 | 1494 | 81 | **157.81** | 42 |
| **2017** | 124 | 7 | 868 | 49 | **154.50** | -19 |
| **2016** | 143 | 5 | 715 | 25 | **151.87** | -25 |
| **2015** | 168 | 3 | 504 | 9 | **147.87** | 15 |
| **2014** | 153 | 1 | 153 | 1 | **144.55** | -6 |
| **2013** | 159 | -1 | -159 | 1 | **141.24** | 37 |
| **2012** | 122 | -3 | -366 | 9 | **137.92** | -34 |
| **2011** | 156 | -5 | -780 | 25 | **134.61** | 26 |
| **2010** | 130 | -7 | -910 | 49 | **131.29** | 22 |
| **2009** | 108 | -9 | -972 | 81 | **127.98** | - |

**Table 5.** Most prolific institutions

| Position | Institution | Publications | % |
|---|---|---|---|
| 1 | University of Hertfordshire | 6 | 0.29 |
| 2 | Arizona State University | 4 | 0.19 |
| 3 | Department of Physics and Astronomy, University of Pittsburgh | 4 | 0.19 |
| 4 | Sport Medicine Centre, University of Calgary | 4 | 0.19 |
| 5 | University of Cape Town | 4 | 0.19 |
| 6 | University of California | 4 | 0.19 |
| 7 | University of Colorado | 4 | 0.19 |
| 8 | University of Pittsburgh | 4 | 0.19 |

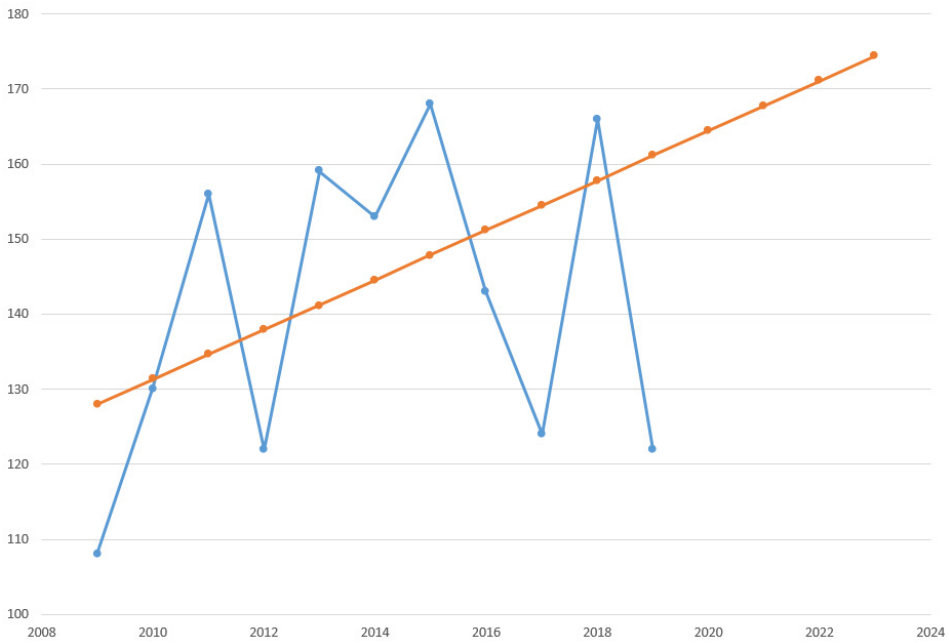



**Figure 4.** Tendency analysis graph of the number of publications per year

### 3.3 Institutions and Countries

**Most prolific institutions.** Table 5 presents the most productive institutions in ARS Scopus-indexed literature. The ones that stood out among the rest were: University of Hertfordshire with 6 publications that represents a percentage of 0.29%; and with 4 publications (0.19%) Arizona State University, University of Pittsburgh, University of Calgary, University of Cape Town, University of California, University of Colorado, and University of Pittsburgh.

**Geographical distribution of the publications.** The countries where most publications are produced are listed in Table 6. The country was taken from the affiliation listed in the articles for each author. The percentage was calculated by dividing the number of publications from each country by the total number of publications retrieved from the database (i.e.: 2015). United States was the country in which more literature was produced with almost 45% of publications followed by United Kingdom with a total of 179 manuscripts. Figure 5 represents the countries with publications in a map, and highlights countries with more than 150 publications, countries with more than 50 publications and countries with less than 50 publications.

**Table 6.** Geographical distribution of the publications

| Position | Country | Publications | % |
|---|---|---|---|
| 1 | United States | 898 | 44.57 |
| 2 | United Kingdom | 179 | 8.88 |
| 3 | Australia | 98 | 4.86 |
| 4 | Canada | 97 | 4.81 |
| 5 | Germany | 78 | 3.87 |
| 6 | China | 67 | 3.33 |
| 7 | Taiwan | 60 | 2.98 |
| 8 | Spain | 57 | 2.83 |
| 9 | Japan | 36 | 1.79 |
| 10 | Hong Kong | 34 | 1.69 |

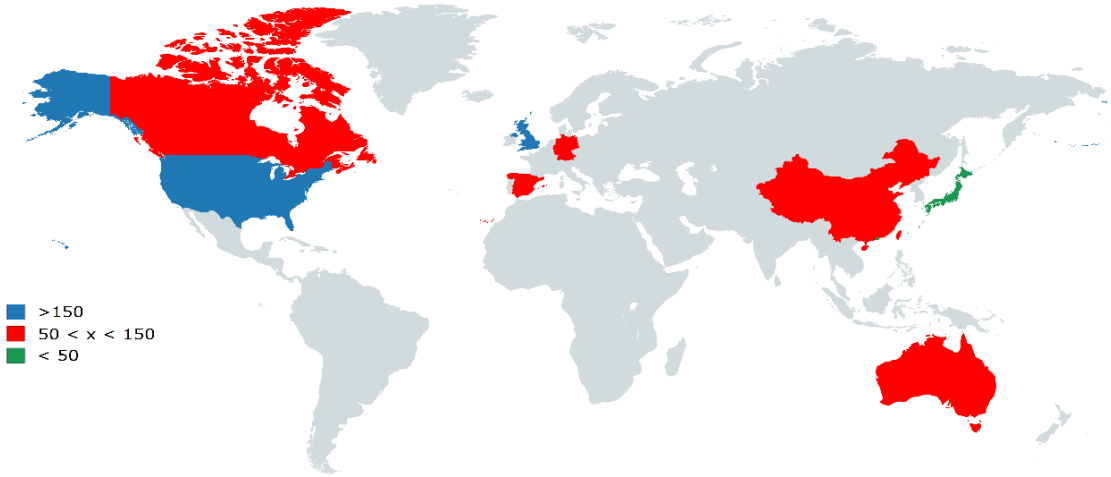



**Figure 5.** Most productive countries

### 3.4 Languages

**Language used in publications.** English was the most common language employed as shown in Table **7**. Moreover, a considerable number of publications were found in Spanish and German languages. A few publications were written in Chinese, Portuguese and French. Japanese, Korean, Czech and Turkish were also found in one publication each.

**Table 7.** Distribution considering the language used

| Position | Language | Publications |
|---|---|---|
| 1 | English | 1984 |
| 2 | Spanish | 14 |
| 3 | German | 11 |
| 4 | Chinese | 5 |
| 5 | Portuguese | 3 |
| 6 | French | 2 |
| 7 | Japanese | 1 |
| 8 | Korean | 1 |
| 9 | Czech | 1 |
| 10 | Turkish | 1 |

### 3.5 Type of Document

**Kind of publications.** More than half of the contributions are published in journals, whereas more than the third part are made it known in conferences, as shown in Table 8. This could be explained by the fact that to reach the potential readers, such as professors, teachers or lecturers provides with more accessibility rather than attending to a conference. In addition, book chapters, reviews and conference reviews were also employed to publish but in fewer numbers (4% of total publications). In a further lower position notes, books, articles in press, short survey, editorial, letter and erratum were found.

**Author's keywords in the publications.** Scopus offers the possibility to retrieve author's keywords and index terms. Author's keywords refer to terms assigned to the document by the author, whilst index terms are controlled vocabulary terms assigned to the document for its management in the database. Author's keywords were chosen in this subsection instead of index keywords due to they were found more interesting and accurate for bibliometric purposes.

The most common authors' keywords employed in the selected publications are presented in Table 9. In addition, in Figure 6 the more a keyword appears in the papers, the larger a tag and the circle around the keyword are. These labels are divided in clusters, in which colors define each one of the clusters [37].

The most frequent keywords were "Clickers" followed by "Active Learning" and "Audience Response System". Others terms were also identified: "Learning", "Technology", "Classroom Response System", "Audience Response Systems", "Student Engagement Student", "Response System Clicker", and "Student Response Systems Education". In all of the cases, the terms found were related to ARS.

**Table 8.** Forms of publications

| Position | Type | Publications | % |
|---|---|---|---|
| 1 | Article | 1052 | 52.21 |
| 2 | Conference Paper | 714 | 35.43 |
| 3 | Book Chapter | 85 | 4.22 |
| 4 | Review | 70 | 3.47 |
| 5 | Conference Review | 47 | 2.33 |
| 6 | Note | 15 | 0.74 |
| 7 | Book | 10 | 0.50 |
| 8 | Article in Press | 7 | 0.35 |
| 9 | Short Survey | 7 | 0.35 |
| 10 | Editorial | 5 | 0.25 |
| 11 | Letter | 2 | 0.10 |
| 12 | Erratum | 1 | 0.05 |

**Table 9.** The most frequently keywords listed the selected publications

| Position | Keyword | Number of publications |
|---|---|---|
| 1 | Clickers | 203 |
| 2 | Active Learning | 134 |
| 3 | Audience Response System | 96 |
| 4 | Learning | 49 |
| 5 | Technology | 49 |
| 6 | Classroom Response System | 49 |
| 7 | Audience Response Systems | 48 |
| 8 | Student Engagement | 48 |
| 9 | Student Response System | 47 |
| 10 | Clicker | 46 |
| 11 | Student Response Systems | 43 |
| 12 | Education | 42 |

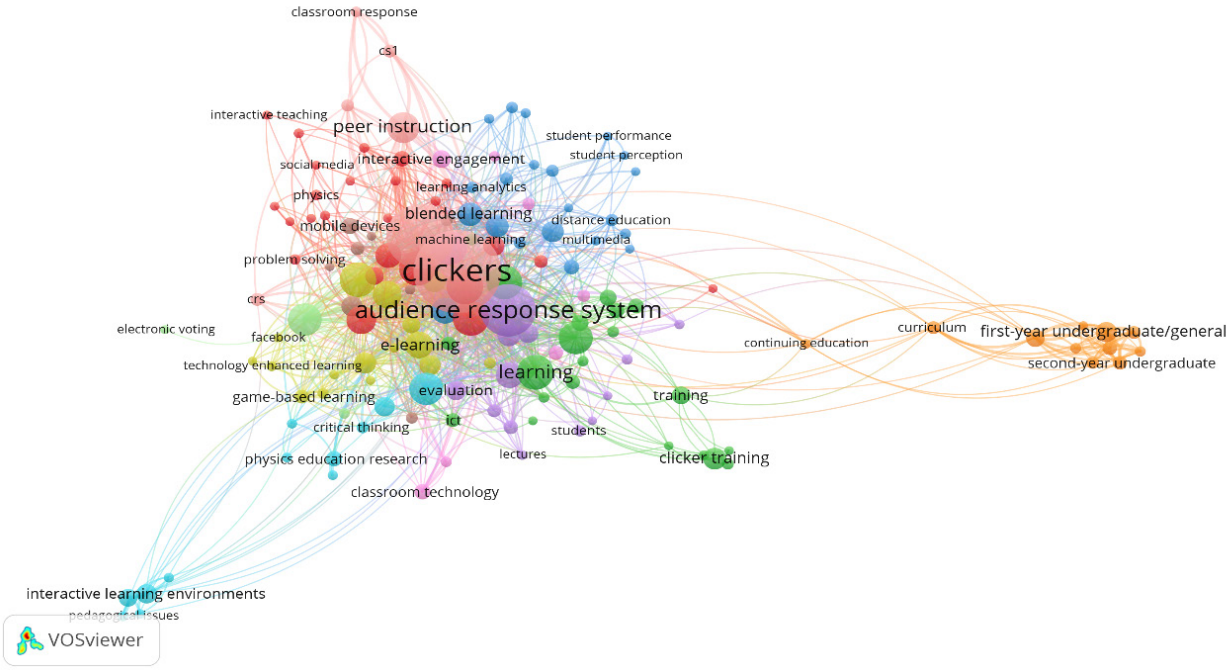



**Figure 6.** Most frequently used keywords

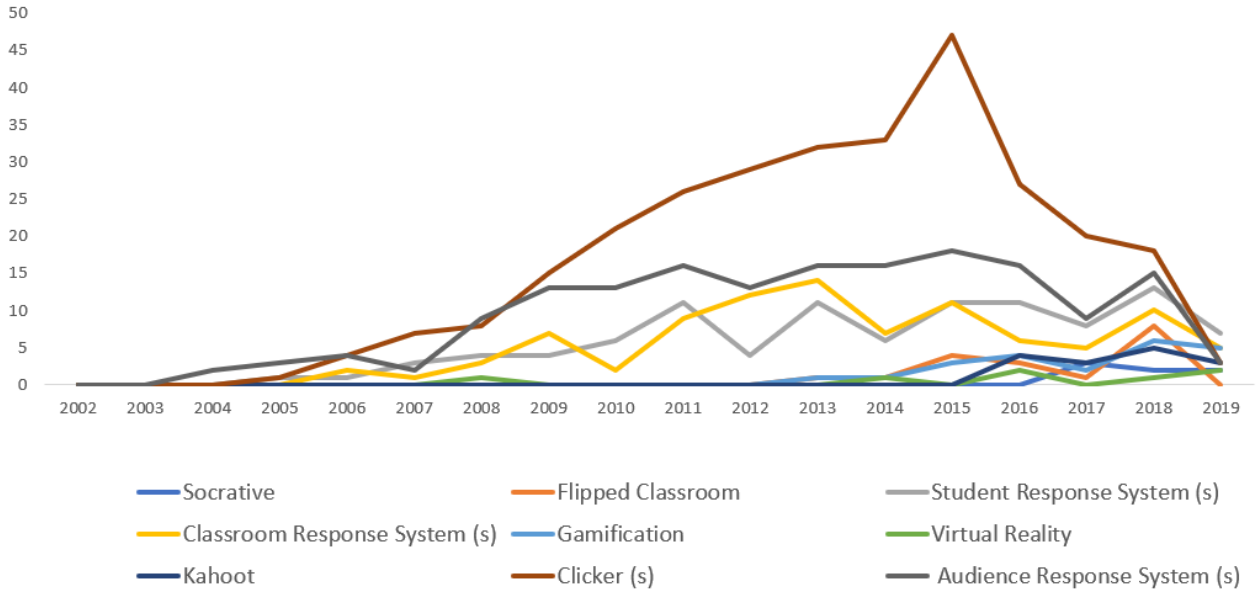



**Figure 7**. Evolution over time of the frequency of keywords

A more in-depth analysis of the evolution over time of the frequency of keywords in the identified papers shows that (see Figure 7):

- Since 2015, there has been a substantial rise in the adoption of gamification [38] principles within ARS in education. This approach involves integrating gamification elements such as rewards and leaderboards into traditional interactive settings [39], leading to increased student engagement, participation, and academic performance [40]. The approach's adaptability allows for its application across diverse disciplines, facilitating improved learning outcomes and promoting a dynamic educational environment [41]. Well-known ARSs such as Kahoot and Socrative appear, as a result of our search string, in 2016 and 2017, respectively.
- In addition, there has been a slight increase in the use of word "Virtual Reality" since 2016. The integration of audience response systems and virtual reality (VR) is a promising technology in higher education, thus holding immense potential for transformative learning experiences.
- Another word that is increasing its frequency of occurrence in papers in 2015 is Flipped Classroom**.** The integration of audience response systems and the flipped classroom model in higher education holds significant potential for enhancing the learning process [42]. Through audience response systems, students can actively engage with pre-class materials and assessments, promoting a more active and self-directed learning approach. This enables educators to utilize class time for in-depth discussions, collaborative activities, and problem-solving exercises, fostering deeper comprehension and critical thinking skills among students. The combination of audience response systems and the flipped classroom paradigm is expected to optimize learning outcomes, promote student-centered learning, and create a more interactive and effective educational environment in higher education.

### 3.6 Author Production

This subsection shows **the number of authors** with variables such as: (i) author participants' productivity; (ii) authorship trend analysis; and (iii) most prolific authors.

**Author participants' productivity.** To estimate the mean author participants' productivity, the number of authors in a year is divided by the number of paper in the same year, as shown in (16). In addition, the inverse of this parameter revealed the mean productivity per participant author (17).

$$AAPP = \overline{AuthorsPerPaper} = \frac{NumberOfAuthors}{NumberOfPapers}. \quad \textbf{(16)}$$

$$PPP = ProductivityPerAuthors = \frac{1}{AuthorsPerPaper}. \quad \textbf{(17)}$$

The values of these parameters are exposed in Table 10. The number of authors per paper (AAPP) varied from a minimum of 2.52 in 2012 to a maximum of 3.67 in 2019. Despite the variation of this parameter throughout the years, the values around 3.5 were found as of 2016, and the values around 2.5 appeared between 2010 and 2012. This indicates an increase of this parameter. Nevertheless, the mean value of productivity per author (PPP) decreased. Note that this parameter was around 0.4 from 2010 to 2012 whilst from 2013 to 2019 PPP changed around 0.3.

**Table 10.** Author productivity

| Year | Papers | Authors | AAPP | PPP |
|---|---|---|---|---|
| 2019 | 118 | 433 | 3.67 | 0.27 |
| 2018 | 166 | 579 | 3.49 | 0.29 |
| 2017 | 124 | 444 | 3.58 | 0.28 |
| 2016 | 143 | 480 | 3.36 | 0.30 |
| 2015 | 168 | 502 | 2.99 | 0.33 |
| 2014 | 153 | 479 | 3.13 | 0.32 |
| 2013 | 159 | 517 | 3.25 | 0.31 |
| 2012 | 122 | 307 | 2.52 | 0.40 |
| 2011 | 156 | 453 | 2.90 | 0.34 |
| 2010 | 130 | 348 | 2.68 | 0.37 |
| 2009 | 576 | 1518 | 2.64 | 0.38 |

**Authorship trend analysis.** This parameter allowed studying the number of authors who contributed to the publications. Papers with one author and multiple authors were separated. The total number of papers per year was also considered. All the percentages in Table 11 were calculated by dividing the total output per year by the total number of papers from 2010 to 2019.

The results in the production of ARS literature showed that multiple authors contributed more than single authors from 2010 to 2019. Moreover, the values varied from 5.98% in 2012 to 9.52% in 2015, and no increasing or decreasing trend was found in the values. With respect to the single author production, no important differences were found throughout the years, although some peaks in literature production stood out in 2011, 2012 and 2015.

**Table 11.** Authorship trend analysis

| Year | Single author | | Multiple author | | 0 to N authors |
|---|---|---|---|---|---|
| | Total output | % | Total output | % | Total output |
| 2019 | 20 | 1.39 | 96 | 6.67 | 118 |
| 2018 | 24 | 1.67 | 135 | 9.38 | 166 |
| 2017 | 28 | 1.95 | 94 | 6.53 | 124 |
| 2016 | 26 | 1.81 | 112 | 7.78 | 143 |
| 2015 | 29 | 2.02 | 137 | 9.52 | 168 |
| 2014 | 27 | 1.88 | 121 | 8.41 | 153 |
| 2013 | 23 | 1.60 | 130 | 9.03 | 159 |
| 2012 | 33 | 2.29 | 86 | 5.98 | 122 |
| 2011 | 44 | 3.06 | 109 | 7.57 | 156 |
| 2010 | 28 | 1.95 | 97 | 6.74 | 130 |
| TOTAL | 282 | 19.60 | 1117 | 77.62 | 1439 |

**Most prolific authors.** In Table 12 the most prolific authors in the ARS literature are depicted. These authors are Daniel Zingaro from the Department of Mathematical and Computational Sciences at the University of Toronto with 10 publications; Leo Porter from the Department of Computer Science and Engineering at the University of California, San Diego and Steven Pollock from the Department of Physics, both with 9 publications each; and Bill Jay Brooks from the School of Chemical, Biological and Environmental Engineering at the Oregon State University with 8 publications. The percentages in Table 12 were calculated, dividing by 2015 the total number of publications considered in this paper.

**Table 12.** Most prolific authors

| Position | Author | Publications | Percentage |
|---|---|---|---|
| 1 | Zingaro D. | 10 | 0.49 |
| 2 | Porter L. | 9 | 0.44 |
| 3 | Pollock S. | 9 | 0.44 |
| 4 | Brooks B.J. | 8 | 0.39 |
| 5 | Chan K. | 6 | 0.29 |
| 6 | Kinght J.K. | 6 | 0.29 |
| 7 | Kung S.Y. | 6 | 0.29 |
| 8 | Li X. | 6 | 0.29 |
| 9 | Liao Y.F. | 6 | 0.29 |
| 10 | Liu Y. | 6 | 0.29 |
| 11 | Lo J. | 6 | 0.29 |
| 12 | Mak M.W. | 6 | 0.29 |

### 3.7 Journal Productivity

This subsection presents an analysis of the scatter of journal productivity.

**Most preferred sources.** The sources where more publications appeared are shown in Table 13. In addition, a percentage was calculated with the total number of publications. The most preferred sources can be divided into journal and conference papers. In the first places, the ASEE conference proceeding with 90 publications (4.45%), Proceedings - Frontiers in Education Conference, FIE with 38 publications (1.88%) and Lecture Notes in Computer Science with 35 publication (1.73%) were the most common sources to find literature related to ARS. The most targeted journals were Journal of Chemical Education with 28 publications (1.38%) and Computers and Education with 24 publications (1.18%). Conferences papers stood out among journal papers. Moreover, three times more papers were published at the ASEE Annual Conference and Exposition, Conference Proceedings than in the next most prolific source, Proceedings - Frontiers in Education Conference, FIE.

**Table 13.** Most preferred sources

| Position | Source | Publications | % |
|---|---|---|---|
| 1 | ASEE Annual Conference and Exposition, Conference Proceedings | 90 | 4.45 |
| 2 | Proceedings - Frontiers in Education Conference, FIE | 38 | 1.88 |
| 3 | Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) | 35 | 1.73 |
| 4 | Journal of Chemical Education | 28 | 1.38 |
| 5 | Computers and Education | 24 | 1.18 |
| 6 | AIP Conference Proceedings | 23 | 1.13 |
| 7 | CBE: Life Sciences Education | 19 | 0.94 |
| 8 | American Journal of Physics | 18 | 0.89 |
| 9 | Audience Response System in Higher Education: Applications and Cases | 17 | 0.84 |
| 10 | Communications in Computer and Information Science | 17 | 0.84 |

### 3.8 Scientific Collaboration

This section studies the collective efforts to produce ARS literature. To this end, the following parameters were obtained: (i) the degree of collaboration, (ii) the collaboration index (CI), (iii) the co-authorship index (CAI), and (iv) the research networks [36].

### 3.9 Collaboration Index (CI)

**Degree of collaboration.** From the data in Scopus the degree of collaboration among the authors, and their cooperation tendency was analysed (18). Table 14 showed that the majority of the publications were authored by 1, 2 and 3 authors, which represents the 68.17%. The number of publications with 4 or more authors decreased as the number of authors increased. Only in a few publications appeared nine or more authors. The degree of collaboration (C) was 0.779. To calculate this parameter the anonymous papers were discarded (51 publications, 2.53% of the 2015 publications found).

$$C = \frac{Publications_{multipleAuthors}}{Publications_{multipleAuthors} + Publications_{singleAuthor}}. \quad (18)$$

**Table 14.** Authorship pattern of publications

| Position | Number of authors | Number of publications | % |
|---|---|---|---|
| 0 | Anonymous | 51 | 2.53 |
| 1 | Single author | 434 | 21.53 |
| 2 | Two authors | 502 | 24.91 |
| 3 | Three authors | 438 | 21.73 |
| 4 | Four authors | 271 | 13.44 |
| 5 | Five authors | 143 | 7.09 |
| 6 | Six authors | 86 | 4.26 |
| 7 | Seven authors | 29 | 1.43 |
| 8 | Eight authors | 23 | 1.14 |
| 9 | Nine authors | 9 | 0.44 |
| 10 | Ten authors | 6 | 0.29 |

**CI.** The collaboration index in the literature related to ARS was studied in this section (19). CI had a value around 3 since 2013 and almost reaches the value of 4 in 2019. The number of multi-authored publications and the total authors in the multi-authored publications pointed out a collaborative scenario among the authors (see Table 15).

$$CI = \frac{SignatoriesInMultiauthoredPublications}{MultiauthoredPublications}. \quad (19)$$

### 3.10 National and International Collaborations

The collaboration profile in the literature can be defined depending on whether the researchers involved are from different countries or institutions. These collaborations may have a nature of:

**- International**, when the authors come from different countries.

**- National**, when the authors work in different institutions in the same country.

**- No collaboration.**

Figure 8 shows a graphical representation of these collaborations. 7 depicts that there is a decrease in collaboration in 2019, and that the majority of authors cooperate with others national researchers or of the same affiliation. Only few authors did have international collaborations.

**Table 15.** Collaboration index

| Year | Multi-authored publications | Total signatories in multi-authored publications | CI |
|---|---|---|---|
| 2019 | 116 | 433 | 3.73 |
| 2018 | 159 | 579 | 3.64 |
| 2017 | 122 | 444 | 3.63 |
| 2016 | 138 | 480 | 3.47 |
| 2015 | 166 | 502 | 3.02 |
| 2014 | 148 | 479 | 3.23 |
| 2013 | 153 | 517 | 3.37 |
| 2012 | 119 | 307 | 2.57 |
| 2011 | 153 | 453 | 2.96 |
| 2010 | 125 | 348 | 2.78 |
| 2009 | 107 | 314 | 2.93 |

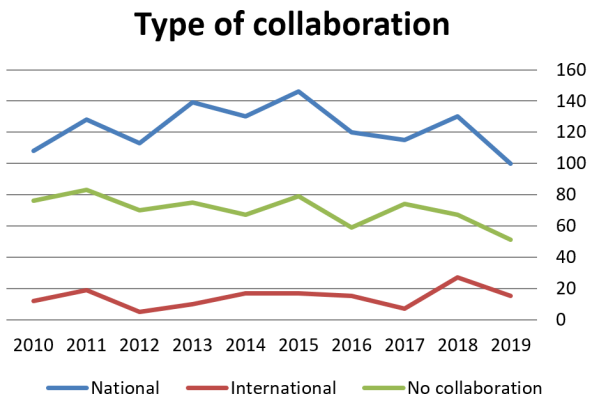


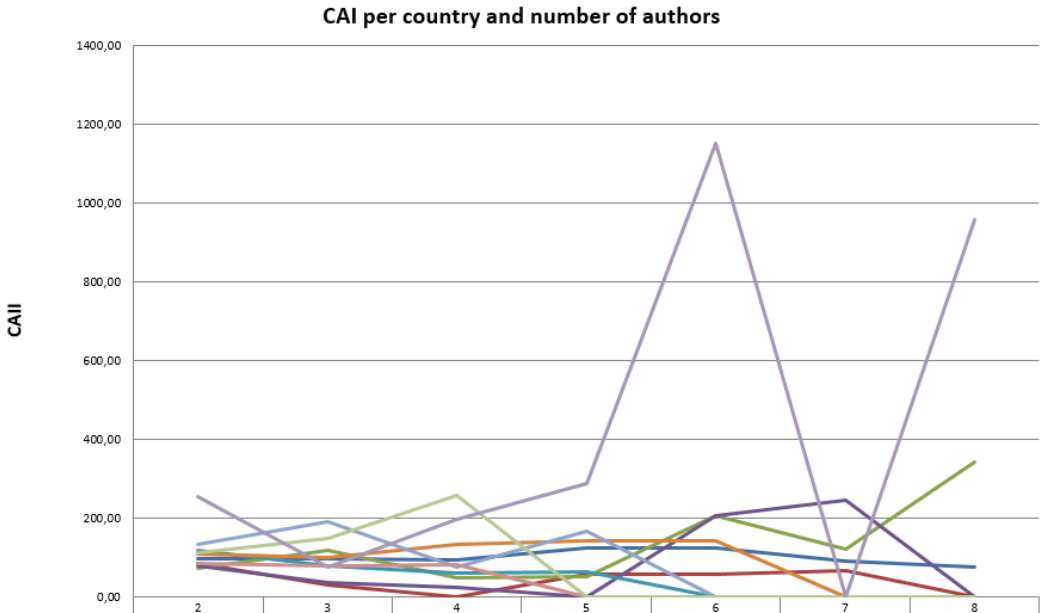

**Figure 8.** Collaboration pattern in selected publications

### 3.11 CAI

CAI is proposed to investigate whether the number of publications in a country corresponds to the average within a co-authorship pattern. This parameter is calculated according to (20), by considering the number of single-authored, two-authored, three-authored, multi-authored publications from different countries of different sub-disciplines in a proportional manner.

There are seven CAI values, as shown in Figure 9, for the ten pioneer countries in ARS literature. Hong Kong achieves high CAI values for two-, five-, six-, and eight-authored papers; Japan for four-authored papers; Taiwan for three-authored papers and Canada for seven-authored papers.

$$CAI = 100 \cdot \left( \left( N_{ca} / Nct \right) / \left( N_{ta} / N_{tt} \right) \right). \quad \textbf{(20)}$$




| | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| United States | 97,24 | 97,97 | 95,54 | 123,55 | 123,55 | 92,50 | 74,88 |
| United Kingdom | 85,72 | 29,75 | 0,00 | 56,28 | 56,28 | 66,22 | 0,00 |
| Australia | 74,17 | 117,75 | 47,27 | 51,40 | 205,61 | 120,95 | 342,69 |
| Canada | 79,10 | 36,60 | 23,88 | 0,00 | 207,73 | 244,39 | 0,00 |
| Germany | 119,07 | 79,66 | 59,39 | 64,58 | 0,00 | 0,00 | 0,00 |
| China | 109,60 | 101,45 | 132,35 | 143,93 | 143,93 | 0,00 | 0,00 |
| Taiwan | 134,60 | 192,33 | 77,20 | 167,92 | 0,00 | 0,00 | 0,00 |
| Spain | 85,01 | 77,87 | 81,27 | 0,00 | 0,00 | 0,00 | 0,00 |
| Japan | 112,17 | 147,94 | 257,34 | 0,00 | 0,00 | 0,00 | 0,00 |
| Hong Kong | 253,82 | 76,09 | 198,52 | 287,86 | 1151,43 | 0,00 | 959,52 |

**Figure 9.** The co-authorship index plot

### 3.12 Research Networks

They can be found in literature depending on a dimension of interest, which can be author, institution or country among others. In this section the author's dimension was analyzed. Figure 10 depicts a map of authors' groups that worked together in the same area. These groups were calculated by a clustering technique implemented in the VOSviewer tool, to show whether these groups have co-authored a number of publications indexed in Scopus [37].

### 3.13 Author Citation Analysis

This section presents an analysis of author's citations in order to expose connections between the authors and the most cited publications. A co-citation study will also be carried out to reveal the cooperation among the researchers.

### 3.14 Most Cited Publications

The publications were sorted by the number of citations in Scopus. Results show that the most frequently cited articles were "Interactive-engagement versus traditional methods:

A six-thousand-student survey of mechanics test data for introductory physics course", with 2,365 citations, "Clickers in the large classroom: Current research and best-practice tips", with 597 citations and "Why peer discussion improves student performance on in-class concept questions", with 439 citations.

### 3.15 Co-citation Analysis

The co-citation is produced when two authors are cited in the same publication. The network mapping which reveals the co-citation of authors is shown in Figure 11. Nine clusters were identified as the most commonly co-cited groups of authors. None of the groups stood out from the rest, thus implying that their research is not related.

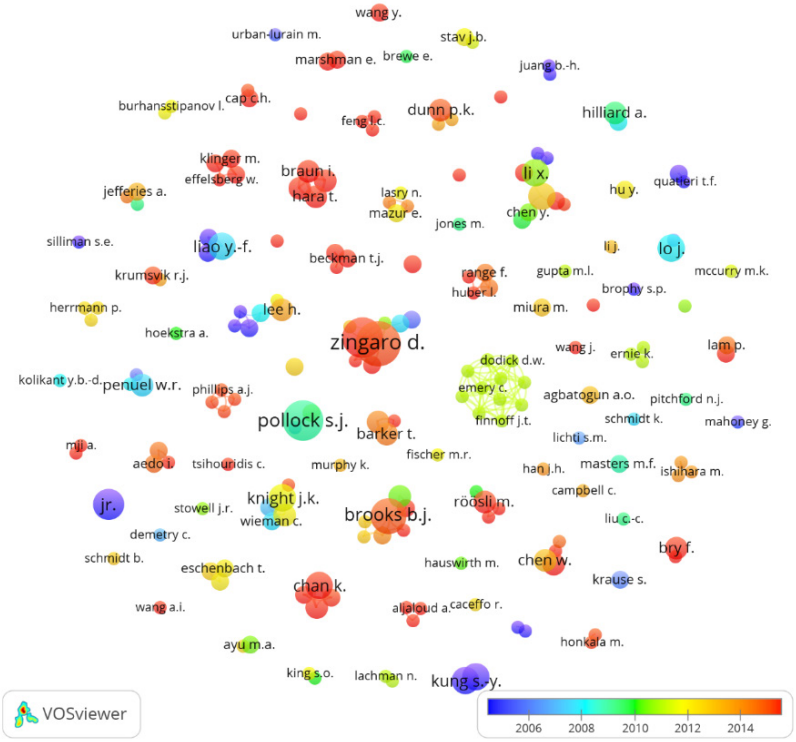



**Figure 10.** Overlay visualization of the most relevant authors in each cluster based on co-authorship

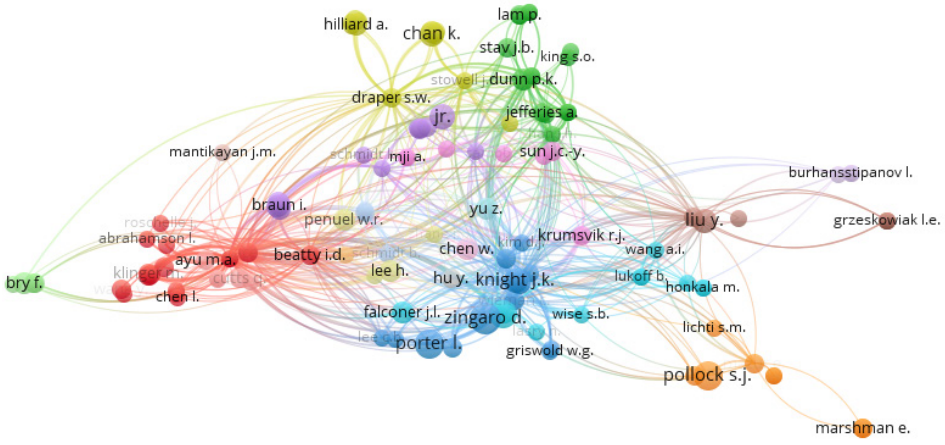



**Figure 11.** Network map displaying co-citation of authors

# 4 Discussion

This paper presents the current literature situation related to ARS for education retrieved from Scopus. Results showed that researchers working on ARS were more productive in the last ten years. However, a remarkable decrease in publications has been noticed in 2019 (AGR in 2019 = -28.92), which might indicate that this research field has reached a certain level of maturity and requires innovative solutions. This is also confirmed by the fact that the majority of the studies retrieved in Scopus were published in journals (52.21% of total publications). Journals are the markers of research fields [43]. When changes in a research field occur in short periods, one of the quickest ways to disseminate the results to the scientific community is through conference publications, but only 35.43% of studies found in Scopus were conference publications.

However, conferences proceedings are in the top three most preferred sources of publications: ASEE Annual Conference and Exposition (not ranked in CORE, but was ranked B in ERA2010; SJR 2018: 0), IEEE Frontiers in Education Conference (ranked B in CORE 2018; SJR 2018: 0.16), and Lecture Notes in Computer Science (not ranked in CORE; SJR 2018: 0.28). The most preferred journals are: Journal of Chemical Education (Q2 in JCR 2018), and Computers and Education (Q1 in JCR 2018). The journal Computers and Education has published two articles among the top ten cited publications in the field. The most cited publication [44] was published when this field was in its infancy. This publication was cited 2365 times according to Scopus and 6583 times according to Google Scholar. It was authored by only one author, which is also the case for the second most cited publication [45].

Notice that the interdisciplinary nature of this field is evident. ARS has been used in education for different disciplines: computer science, nursing, biology, physics, animal behaviour science, chemistry, life sciences, pharmacy, financial accounting and psychology, among others. The factors which seem to be most influential in terms of student learning are engagement, interaction, anonymity, questioning, instant feedback and technological benefits and limitations [46]. The increasingly ubiquitous presence of this teaching tool will allow the transfer of understandings on these factors in one discipline to another.

The majority of publications were authored by multiple authors, however a considerable number of single-authored papers exists. This might be explained by the fact that many of these authors wrote a paper to reflect their own experience using ARS in the classroom. Some higher education institutions promote single-author and first-author publications [47-48] and some researchers may single-author their more important work to enhance their reputations [49]. However, it has been shown that acceptance rate of papers which are collaboratively authored tends to be higher than that for single-authored papers [50].

The countries that produced most literature related to ARS were native English-speaking developed countries: the US (44.57% of total publications), the UK came far behind in the second place with 8.88% of publications, followed by Australia (4.86%) and Canada (4.81%). These results concerning the top productive country confirm findings reported in a previous bibliometric study on the application of technology in classroom dialogue [21]. These countries were those that have the highest number of startup organizations. Surprisingly, Asian regions that are well-known of the use of technology were at the bottom of the list with less than 2% in the case of Japan and Hong Kong. African and Latin American countries were absent from the top ten list. Our findings are confirmed by a previous meta-analysis on the effect of ARS on academic performance [51]. This result can be explained by the fact that these developing countries face many challenges regarding education and that the priority of their researchers does not lie in investigating the use of ARS. However, with the cost of mobile phones and other devices becoming cheaper, we expect to see more studies from developing countries about this subject. The US department of education in a report published in 2017 recommended the use of technology to "give students, educators, families, and other stakeholders timely and actionable feedback about student learning to improve achievement and instructional practices" [52]. There is therefore support from the policy makers in the US to promote the use of ARS, which might not be the case in other countries [53].

The majority of the multi-authored publications were produced by national collaboration. This can be explained by the fact that usually when investigating or proposing a pedagogical approach or tool, the researchers belong to the same affiliation or collaborate in a national project. For this reason, there are few international collaborations in this field to produce publications. However, there might be a rise in international collaboration if there are capacity building projects in education that support the use of technology in developing countries. The EU is known for funding the Erasmus+ program for capacity building projects. However, only two European countries, Germany and Spain, are in the list of top ten countries producing literature about ARS.

Daniel Zingaro (University of Toronto Mississauga), and Steven J. Pollock (University of Colorado Boulder) are the most prolific authors with more than eight publications. Zingaro has been contributing to literature over the last decade while Pollock's contributions were more concentrated in a short period of time between 2008 and 2010 as shown in Figure 10. Zingaro and Leo Porter (University of California at San Diego) collaborate in this field and co-cite each other works as shown in Figure 11.

The most influential study was published in the physics education context. and combine detailed evidence into study-considered higher education.

### 4.1 Future Trends

Based on our analysis, some potential new directions for ARS research are identified:

- Student response system, audience response system, classroom response system and clicker are terms that refer to the technology addressed in this study. While in the early years students used handheld devices, commonly referred to as clicker, to answer questions, the use of this term is declining in recent years, in

favor of student response system, audience response system and classroom response system.

- ARS allows the use of artificial intelligence [54-56], capable of understanding natural language and the code of various programming languages. For example, the potential of using the ChatGPT API in an ARS is enormous: automatic generation of questions of any modality, automatic evaluation of answers, correction and detailed explanation of computer programs and algorithms, among others. The integration of the ChatGPT capabilities with an ARS is illustrated in the tool Arsyc (https://arsyc.com).
- As technology advances, the prospects indicate personalized gamification experiences of ARS tailored to individual student preferences, type of player and learning styles will be achieved [40].
- The integration of virtual reality (VR) can further elevate interactive experiences and revolutionize audience engagement and learning outcomes in various educational and training contexts. By leveraging VR technology, instructors could create immersive and dynamic experiences, enhancing audience participation and comprehension. VR enables real-time visualization of complex concepts, promoting deeper understanding and retention of knowledge. Moreover, the incorporation of interactive elements in VR-based audience response systems will boost instantaneous feedback [57-58].

# 5 Conclusion

This paper can help researchers to recognize significant changes and trends in the literature of ARS. Results showed that although this subject has attracted more attention in the last decade, there is a significant decrease in 2019. The results showed also that the majority of publications were produced in the US and were multi-authored in national settings. The main publication channels used were journals followed by conferences.

Based on the results of this bibliometric analysis, the following suggestions were formulated:

- There is a need for the pioneers' institutions in this field to explore collaboration with institutions in developing countries to conduct research on the use of ARS for education in these countries.

- Researchers should be encouraged to submit their research on ARS to rigorous and prestigious publication venues.

- Researchers willing to solely author their papers might find this research area interesting to explore. Results showed that the number of single-authored papers is one-fifth of all Scopus-indexed literature. Moreover, the two most cute papers are single-authored papers.

- Researchers or faculty looking to learn more about ARS for education can spend short stays in the pioneer institutions listed in Table 6 or seek collaboration with researchers listed in Figure 9.

This study might have several limitations, such as: (i) the search was conducted only in Scopus which might impact on the final results. However, Scopus is one of the largest databases that indexes several publications that are already indexed in other databases; and (ii) the search string might not contain relevant words to this topic. However, we included an extensive list of terms, which alleviates this risk.

Studies with publication from other digital databases should be conducted in the future to complete the results and to verify whether there is a change on the publication trend after 2019. The mapping study will allow researchers to set the basis for a systematic literature review that can provide an in-depth analyse of the quality of the ARS approaches used in literature.

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