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Trends in antimicrobial resistance education research: a bibliometric analysis

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ABSTRACT

Background: Antimicrobial resistance (AMR) poses a severe public health threat, with educational interventions recognized as pivotal in mitigating its impact. The World Health Organization (WHO) Global Action Plan on AMR emphasizes awareness and education as fundamental strategies. Given the complex interplay between human, animal, and environmental health in the development and spread of AMR, educational initiatives are increasingly being framed within a One Health approach. This study aims to examine the scientific production on AMR education of healthcare professionals and the general population.
Methods: A bibliometric analysis was performed on AMR education literature on the Web of Science Core Collection database up to December 2023. Using the Biblioshiny tool within the Bibliometrix R package, the analysis covered productivity metrics, citation impact, keyword co-occurrence, and thematic mapping.
Results: The study analyzed 1124 documents published on AMR education between 1995 and 2023, with a 20.5 % annual growth in publications. Key journals included *Antibiotics-Basel* and *PLOS ONE*, while highly cited sources were *Journal of Antimicrobial Chemotherapy* and *Clinical Infectious Diseases*. The University of London and the US led in institutional and country contributions. Keywords like "knowledge", "attitudes", and "stewardship" were central, reflecting the focus on educational initiatives. Thematic evolution revealed significant growth, with the number of themes increasing from four in 1995–2008 to 20 by 2021–2023, demonstrating the dynamic and expanding nature of research in this field.
Conclusions: The expansion of AMR education research reflects growing global commitment to combating AMR through targeted educational strategies. Framing AMR education within the One Health approach may enhance its effectiveness, by addressing the interconnected drivers of resistance across sectors. Our findings highlight the importance of sustaining international collaboration and aligning AMR educational efforts with national policies. Future research should emphasize interdisciplinary approaches and innovative methods to address the complex challenges of AMR across diverse populations.

1. Introduction

Antimicrobial resistance (AMR) is recognized as a critical threat to public health worldwide, potentially undermining decades of medical progress. The World Health Organization (WHO) has identified AMR as one of the most ten pressing public health threat to humanity, with an estimated number of 4.71 million deaths associated with drug-resistant bacterial infections in 2021 alone, of which 1.14 million were directly attributable to AMR [1,2].

The burden of AMR is related to various factors, including the overuse and misuse of antibiotics in clinical settings, as well as the extensive adoption of antibiotics in agriculture and animal husbandry [3]. The widespread antibiotic use accelerates the evolution of resistant strains, diminishing the effectiveness of standard treatments and leading to increased morbidity, prolonged hospitalizations, higher healthcare costs, and elevated mortality rates compared to infections caused by

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non-resistant pathogens [4]. The global impact of AMR is profound, and it is increasing, albeit with differences among regions and countries. In particular, it was estimated that 178,000 (154,000–202,000) DALYs in 2021, were associated with and attributable to AMR, with projections for 2050 suggesting an increase to 201,000 (165,000–245,000) DALYs [2]. Moreover, without a change in trends, approximately 10 million deaths are expected by 2050 [5]. In addition to its extensive health burden, AMR carries significant economic repercussions. The World Bank Projections indicate that AMR could lead to an additional US $1 trillion in healthcare costs by 2050 worldwide, with annual global gross domestic product (GDP) losses estimated between US $1 trillion and US $3.4 trillion by 2030 [6].

In response to this increasing threat, in 2015 the WHO introduced the Global Action Plan on Antimicrobial Resistance, outlining five strategic objectives: (1) improving awareness and understanding of AMR through effective communication, education, and training; (2) strengthening knowledge and evidence base through surveillance and research; (3) reducing incidence of infection through preventive interventions; (4) sustaining the optimization of antimicrobial medicines usage; (5) increasing investments in new drugs, diagnostics tools, vaccines, and other interventions [7]. Among these objectives, education has emerged as a cornerstone, crucial to improving antibiotic stewardship and understanding AMR across multiple sectors.

Given the widespread misuse of antibiotics across healthcare, agriculture, and community settings, educational interventions must be targeted at a broad range of stakeholders, including healthcare professionals, medical trainees, agricultural workers, animal farmers, and the general population. This strategy aligns with the "One Health Approach", which underscores the interconnected nature of human, animal, and environmental health in addressing AMR [8].

However, the complexity of antibiotic use across different sectors demands that educational interventions must be tailored to meet the unique needs of each target audience [9–11].

In this context, the aim of this study is to conduct a bibliometric analysis, in order to assess the trends of AMR education research, identifying key contributors, emerging themes, and collaboration networks, thereby offering insight to inform and enhance policy and practice in global AMR mitigation efforts.

2. Methods

2.1. Data sources and search strategy

Data were gathered from the Web of Science Core Collection (WoSCC). We used WoSCC following Biblioshiny guidelines, where it is reported as the preferable choice for data quality [12]. Our search covers publications up to December 31, 2023, without time limits. As the screening process started on 13th May 2024, the current year was excluded since it was better to consider only concluded years for our study design. The search strategy was based on keywords "antimicrobial resistance", "antibiotic resistance", "education" and "training", combined in the search string. A screening of titles and abstracts of the records was conducted and only articles published in English and directly focusing on AMR education, knowledge and attitudes of all stakeholders, including involved professionals and the general population, were included.

2.2. Data extraction

The raw data from WoSCC were exported in "plain text" format as a "full record", including for each article authors, title, year of publication, country/region, institution, journal, h-index, g-index and m-index, keywords, and references. Furthermore, citation data were also included in the final dataset.

2.3. Bibliometric analysis

The bibliometric analysis is a rigorous and quantitative methodology for evaluating scientific literature, particularly useful in exploring complex and multidisciplinary domains such as antimicrobial resistance education. This approach leverages citation-based metrics and network analysis to systematically map research trends, identify influential publications, and assess collaborative networks within the field [13].

For instance, a bibliometric analysis on research on antibiotic resistance in *Helicobacter pylori* in the past decade was performed by Yuan et al., while Selva-Pareja et al. conducted a bibliometric analysis on the scientific production on health literacy and education [14,15].

In the context of antimicrobial resistance education, a bibliometric analysis can provide a comprehensive overview of its intellectual structure, thematic evolution, and contries involvement.

Our analysis was conducted using Biblioshiny, within the Bibliometrix package in R version 4.3.3 [12]. A descriptive analysis examined productivity metrics across authors, institutions, and countries, and analyzed publication trends, identifying peaks in the number of publications over time. Citation and co-citation analyses were then conducted to determine the most influential articles and authors, mapping interconnected research clusters within AMR education.

For the keyword and thematic analysis, generic keywords were excluded following a consensus decision by the authors. Additionally, synonyms were grouped under representative terms to ensure conceptual consistency and avoid redundancy in thematic results. Biblioshiny offers a clustering algorithm able to produce thematic clusters which are then presented on a "thematic map", where topics are categorized by centrality (referring to theme relevance) and density (referring to theme development), identifying motor, niche, emerging, and basic themes to outline the core and developing areas within AMR education research.

The temporal trend analysis explored the evolution of AMR education topics over time, focusing on key shifts in research focus. Two reference points were identified: 2008–2009, marked by the creation of the Trans-Atlantic Task Force on Antibiotic Resistance (TATFAR) [16], between the U.S. and European Union, and 2020–2021, impacted by the SARS-Cov-2 pandemic worldwide. All the aforementioned analyses were conducted following the methodologies specific to the software and described on the Bibliometrix website.

3. Results

3.1. Research outputs and annual trends

A total of 1124 documents were published between 1995 (first year

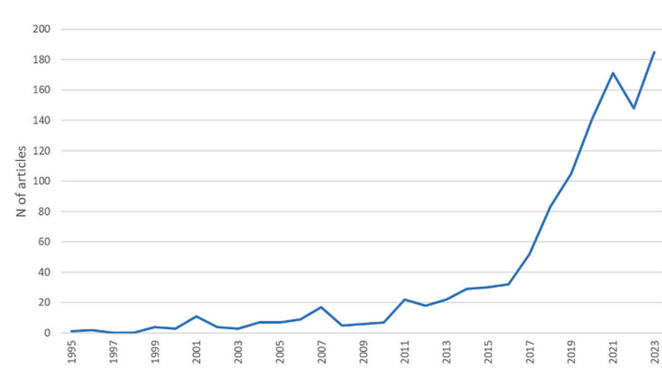

Fig. 1. Annual scientific production on AMR education.
Trend in the number of publications on AMR education from 1995 to 2023. The figure shows a substantial increase in scientific output over time, particularly after 2010, with a peak of 185 articles in 2023. This trend reflects the growing global attention to AMR and the increasing prioritization of educational strategies as part of mitigation efforts.

available) and 2023, with an annual growth rate of publications of 20.5 % (Fig. 1). Initially, the number of publications was low, peaking at just one article in 1995 and experiencing modest increases until 2005. An upward trend began in 2006, accelerating notably post-2010. From 2013 onward, publications surged, reaching 83 articles by 2018 and peaking at 171 in 2021. However, there was a decline in 2022, with publications dropping to 148, before rebounding to 185, the highest registered number of publications, in 2023.

3.2. Source and journal distribution

A total of 390 sources were identified in this analysis, with the most prolific journals being *Antibiotics-Basel* with 105 articles, *PLOS ONE* with 45 articles, and *Antimicrobial Resistance and Infection Control* with 43 articles (Table 1). However, these findings were not entirely consistent with the most cited journals, which included the *Journal of Antimicrobial Chemotherapy* (39 articles, 1692 citations), *Clinical Infectious Diseases* (14 articles, 1407 citations), and *PLOS ONE* (1150 citations) (Table 2). Applying *Bradford's Law*, the core group of the most productive sources comprised 12 journals, accounting for a total of 379 articles, approximately one-third of the total published articles in the field. All these journals focused on antimicrobial resistance, infectious diseases, and public health, while the second group, which was less productive and included 86 journals publishing a combined total of 375 articles, also comprised journals primarily focused on pharmacology and veterinary medicine (Supplementary material).

3.3. Author impact and citation analysis

Among the 6464 identified authors, the most productive was Ashiru-Oredope D., with 20 published articles on the field, followed by Lundborg C.S. with 16 articles, and McNulty C.A.N. with 15 articles (Table 3).

In terms of author impact, Pulcini C. was the most cited author with 166 local citations for 11 published articles, followed by Davey P. and Nathwani D. with 147 citations each, for 6 and 12 articles, respectively (Table 4).

3.4. Institutional and country contributions and collaborations

In terms of institutional contributions, University of London, Egyptian Knowledge Bank, University of Toronto, University of Oxford and Harvard University were among the top institutions, each contributing over 40 publications to the field of AMR education. University of London led with 69 publications.

Geographically, the United States was the leading country with 766 publications, followed by the United Kingdom with 675 publications, Australia with 247 publications, India with 216 publications, and Saudi Arabia with 204 publications (Fig. 2). The dominance by the US, UK and Australia is also reflected in the analysis of corresponding authors' countries, respectively with 183, 164 and 55 articles. Among the three countries, the UK emerged as the one with more collaborations, with 45 % of multiple countries publications (MCP), compared to the 14 % MCP of the US and the 33 % MCP of Australia (Fig. 3). Dense collaboration networks have been identified in the same countries, particularly involving Europe and North America, as shown in the collaboration World map (Fig. 4 and Supplementary material).

Table 1
Most relevant sources, ranked by number of published articles in the field of AMR education.

Sources	Articles	Citations
ANTIBIOTICS-BASEL	105	678
PLOS ONE	45	1150
ANTIMICROBIAL RESISTANCE AND INFECTION CONTROL	43	566
JOURNAL OF ANTIMICROBIAL CHEMOTHERAPY	39	1692
JAC-ANTIMICROBIAL RESISTANCE	31	148
BMC PUBLIC HEALTH	20	397
FRONTIERS IN PUBLIC HEALTH	18	116
INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH	18	270
BMJ OPEN	17	261
INFECTION AND DRUG RESISTANCE	15	221

Table 2
Most relevant sources, ranked by total number of citations for articles in the field of AMR education.

Sources	Citations	Articles
JOURNAL OF ANTIMICROBIAL CHEMOTHERAPY	1692	39
CLINICAL INFECTIOUS DISEASES	1407	14
PLOS ONE	1150	45
LANCET INFECTIOUS DISEASES	695	3
INFECTION CONTROL AND HOSPITAL EPIDEMIOLOGY	694	9
ANTIBIOTICS-BASEL	678	105
ANTIMICROBIAL RESISTANCE AND INFECTION CONTROL	566	43
BMJ-BRITISH MEDICAL JOURNAL	529	1
LANCET	509	1
CLINICAL MICROBIOLOGY AND INFECTION	497	5

Table 3
Most relevant authors, ranked by total number of articles in the field of AMR education.

Authors	Articles	Articles fractionalized
ASHIRU-OREDOPE D	20	2,574,473,699
LUNDBORG CS	16	3,245,852,052
MCNULTY CAM	15	3,758,308,358
FANG Y	14	1,781,721,057
GODMAN B	14	1,860,407,046
SNEDDON J	14	1,878,776,221
HAYAT K	13	1,323,387,723
NATHWANI D	12	2,382,539,683
HAQUE M	11	1,727,073,712
KHAN FU	11	1,431,818,182

Table 4
Most relevant authors, ranked by total number of citations for articles in the field of AMR education.

Author	Citations	Articles
PULCINI C	166	11
DAVEY P	147	6
NATHWANI D	147	12
MCNULTY CAM	119	15
LUNDBORG CS	115	16
SRINIVASAN A	111	3
SINKOWITZ-COCHRAN R	110	2
HAQUE M	100	11
CALS JWL	84	3
ABBO LM	83	3

3.5. Keywords and thematic analysis

The keywords analysis revealed that "*knowledge*" (188 occurrences), "*attitudes*" (160 occurrences), and "*stewardship*" (151 occurrences) were the most frequently mentioned terms. Other commonly occurring terms related to the objectives of educational initiatives included "*prescriptions*" (81 occurrences) and "*self-medications*" (75 occurrences). The temporal frequency analysis indicated that these terms began to appear prominently around the mid-2010s, aligning with annual publication trends on AMR education.

The thematic mapping of keywords identified specific thematic clusters. Motor themes, which include clusters with high density and centrality, were "*Staphylococcus-aureus*" (cluster frequency: 197) and "*animal*" (cluster frequency: 110). Basic themes, such as "*knowledge*"

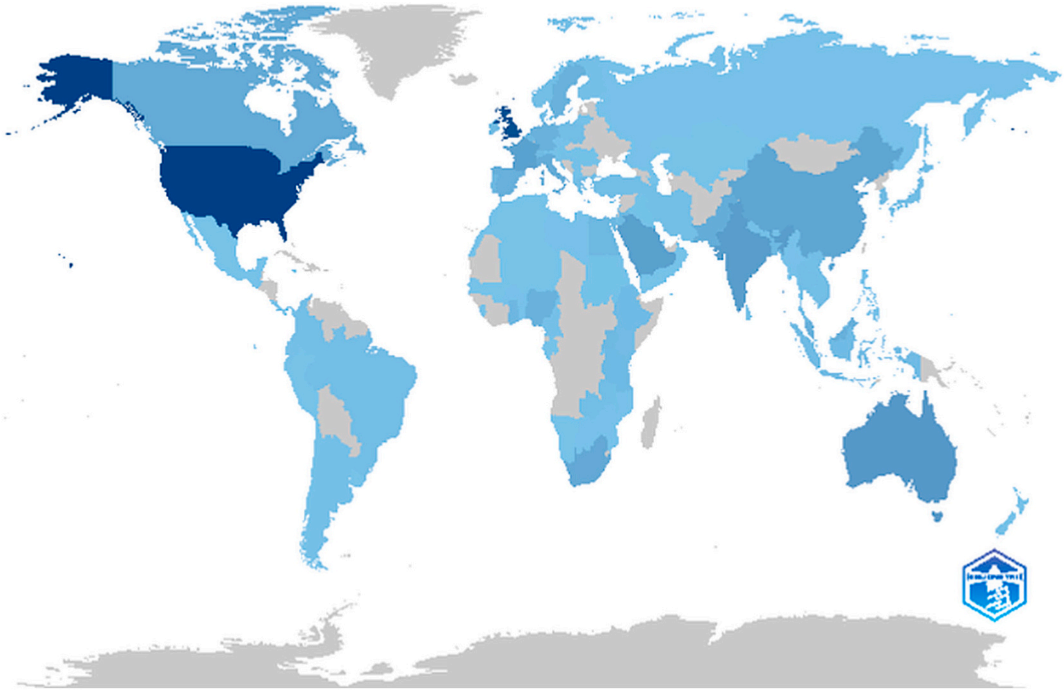

Fig. 2. Distribution of scientific production (number of publications) on AMR education across countries worldwide.
World map showing the number of publications on AMR education by country. Darker shades indicate higher publication volumes. The United States, the United Kingdom, and Australia emerged as the top contributing countries, reflecting their strong engagement in AMR education research and policy development.

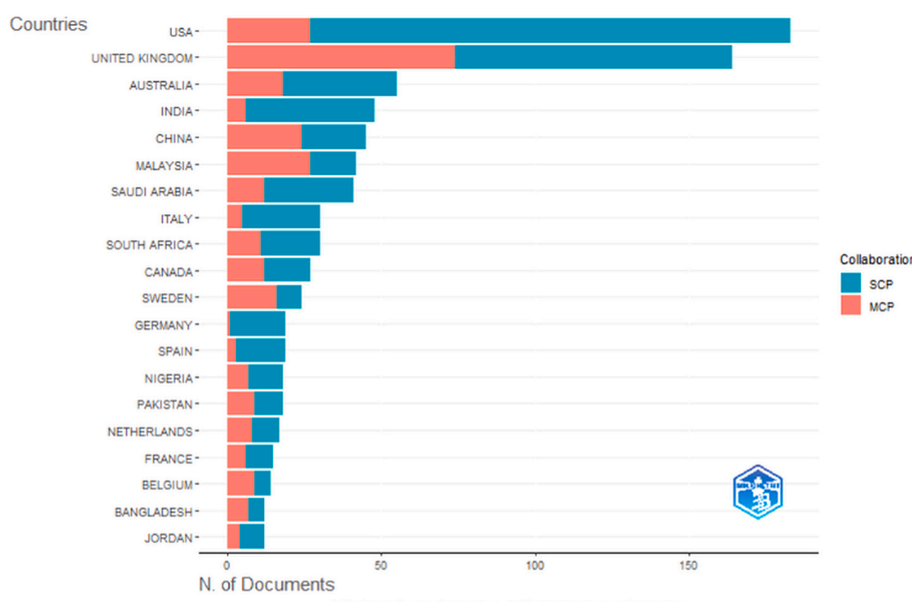

Fig. 3. Corresponding author's countries and collaborations.
Bar chart illustrating the top contributing countries based on the affiliation of corresponding authors. The chart distinguishes between single country publications (SCP) and multiple country publications (MCP), reflecting the extent of international collaboration. The United Kingdom showed the highest proportion of MCP (45 %), followed by Australia (33 %) and the United States (14 %), highlighting differing patterns of international research engagement.

(cluster frequency: 1559) and "*stewardship*" (cluster frequency: 647), appeared less interconnected yet remained essential for understanding core aspects of AMR education (Fig. 5).

3.6. Thematic evolution over time

The thematic evolution analysis reveals a clear progression in research focus over time, with a relevant increase in both the number and diversity of themes. During 1995–2008, 4 main themes were identified: *children* (cluster frequency: 55), *guidelines* (cluster frequency: 50), *Clostridium difficile* (cluster frequency: 6), and *Staphylococcus aureus* (cluster frequency: 55). In the second period (2009–2020), the algorithm highlighted 12 themes, with notable continuities such as *Clostridium difficile* (cluster frequency: 42) and *Staphylococcus aureus* (cluster frequency: 129), alongside emerging topics like *stewardship* (cluster frequency: 488), *knowledge* (cluster frequency: 879), and *health-care*

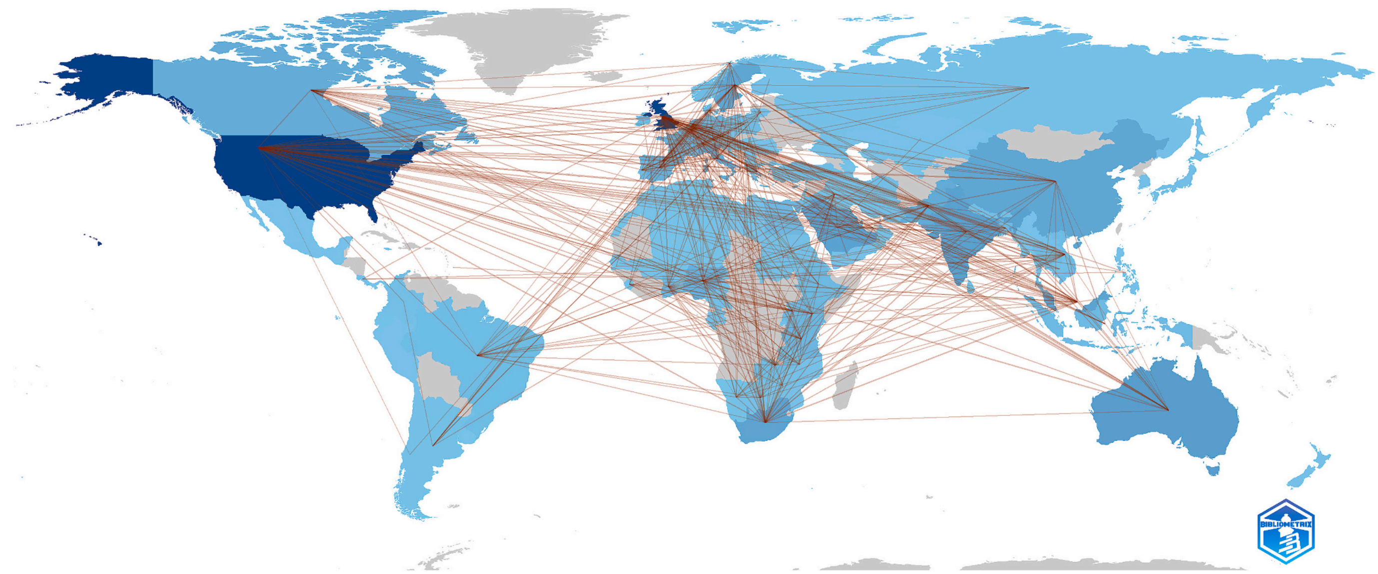

Fig. 4. Collaboration network World map.
World map showing the international collaboration network in AMR education research. Lines represent co-authorship links between countries, and only connections between countries that have collaborated more than twice are shown. Strong collaboration patterns are observed particularly in Europe and North America, highlighting the role of cross-national partnerships in advancing AMR education.

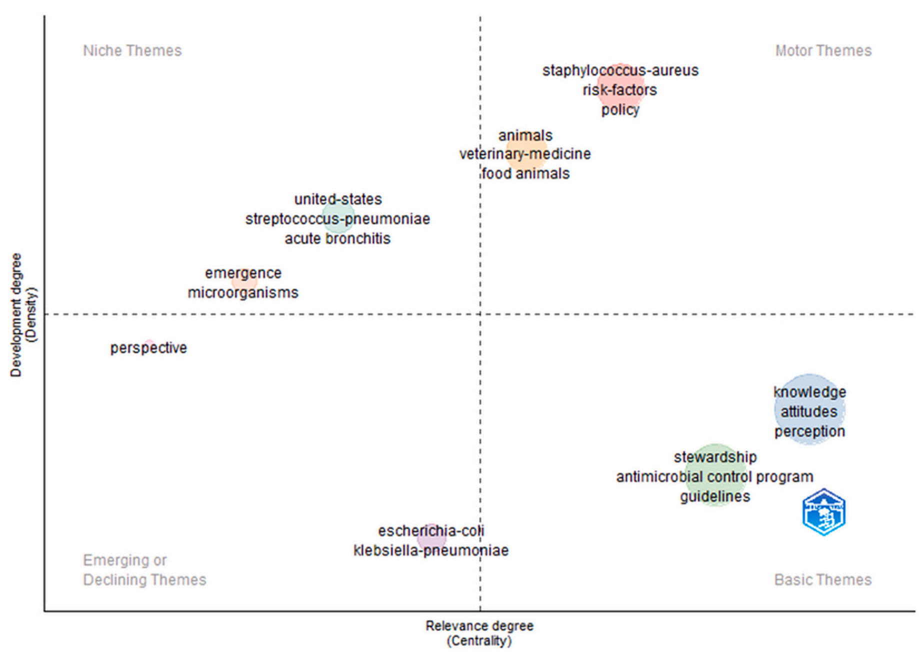

Fig. 5. Thematic map of scientific production on AMR education.
Thematic map based on keyword co-occurrence analysis, plotting clusters according to their centrality (relevance) and density (development). "*Staphylococcus aureus*" and "animals" appear as motor themes, indicating high relevance and strong development. "knowledge" and "stewardship" are identified as basic themes, essential to the field but less internally developed. Niche and emerging or declining themes are also represented, reflecting the diversity and evolution of research topics in AMR education.

workers (cluster frequency: 4). By 2021–2023, the thematic landscape had grown further to encompass 20 distinct themes, with prominent topics including *knowledge* (cluster frequency: 679), *respiratory-tract infections* (cluster frequency: 105), and *bovine respiratory disease* (cluster frequency: 2). Overall, the number of themes increased by 400 % between the first and third periods. While *Clostridium difficile* and *Staphylococcus aureus* persisted into the second period, none of the initial themes remained prominent in the most recent phase. Across the three periods, 8 new themes emerged in 2009–2020, and an additional 14 were introduced in 2021–2023 (Fig. 6). The detailed data about keywords and thematic analysis are available in the Supplementary material.

4. Discussion

This bibliometric analysis examines the scientific production on education and knowledge of professionals and the public population in the field of AMR over the past twenty-five years.

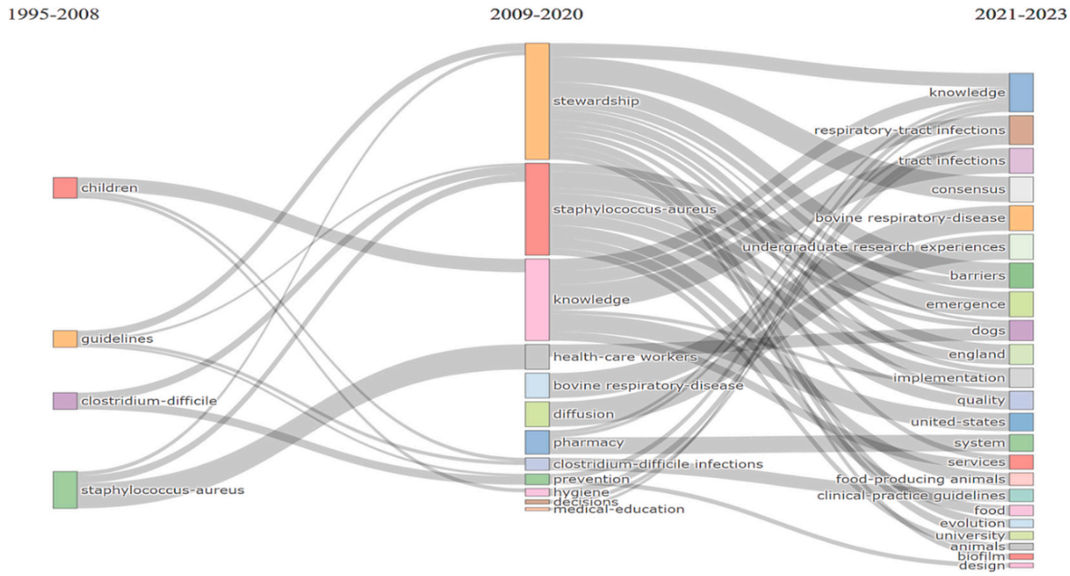

Fig. 6. Thematic evolution of scientific production on AMR education.
Sankey diagram showing the evolution of major research themes on AMR education across three time periods: 1995–2008, 2009–2020, and 2021–2023. Themes such as "*Staphylococcus aureus*", "knowledge", and "stewardship" show continuity and expansion over time, while new topics like "respiratory-tract infections", "barriers", and "implementation" emerged more recently. The increasing number and complexity of themes illustrate the diversification and maturation of the research field.

The substantial growth in research on the AMR education, especially after 2010, reflects the field's response to AMR as an escalating public health threat worldwide. The annual publication growth rate of 20.5 % underscores the scientific and medical communities' prioritization of AMR, consistent with Luz et al.'s finding of a 450 % increase in AMR publications from 1999 to 2018, marking a vibrant expansion in this area of research [17]. Notably, the peak in publications in 2023, with 185 documents, followed by 171 documents in 2021 reflects the intensified focus on AMR education in recent years. This surge can be linked to several factors, including increased funding for AMR research, the implementation of global and national AMR action plans, and the integration of AMR education into medical curricula and public health initiatives [18].

The adoption of innovative educational methods likely contributes to this rise in publications. Farhat et al. highlighted the use of machine learning and interactive platforms in AMR education, opening up predictive and practical applications in AMR research. Such advancements not only enhance research but also broaden educational outreach, reflecting a shift toward more dynamic, technology-driven learning models [19].

The substantial increase in research output on AMR education from 1995 to 2023 can be attributed to several key factors, particularly in countries like the USA, UK, Italy, and Australia.

Firstly, these countries have implemented robust national policies and initiatives aimed at combating AMR. For instance, the WHO has recommended the implementation of antimicrobial stewardship (AMS) programs, which have been widely adopted in these nations [20]. These programs emphasize education as a critical component, driving research and publications in the field [21].

Secondly, the recognition of AMR as a significant public health threat has led to substantial investment in research and education [22]. The USA, UK, Italy, and Australia have prioritized AMR within public health agendas, supported by organizations like the National Institutes of Health (NIH) in the USA, which provides substantial resources for AMR research [23]. In these countries, strong research infrastructures, collaboration between academic and clinical settings, and well-established public awareness campaigns contribute significantly to research volume and public engagement with AMR topics [24–26].

A thematic mapping of AMR education research reveals distinct focal areas. "*Staphylococcus aureus*" and "*animal*" emerged as motor themes due to their high density and centrality. *Staphylococcus aureus* is a major pathogen with a high burden and it is extensively studied for its resistance patterns, resulting in a dense research network. The prominence of this theme highlights the importance of equipping healthcare professionals and researchers with the knowledge to address its clinical and public health impacts [27,28]. Similarly, the role of animals in AMR transmission and development is critical, particularly within the One Health approach, which underscores the need for cross-disciplinary education to foster understanding of the interconnectedness between human, animal, and environmental health [29]. In contrast, "*knowledge*" and "*stewardship*" were identified as basic themes. These broader topics encompass efforts to raise awareness and inform best practices. Antimicrobial stewardship, a key strategy recommended by the WHO, is central to educate healthcare professionals and the public population on minimizing AMR development and spread. While essential, these themes form less dense and central networks compared to specific research areas [30,31].

Finally, the evolution of AMR education research from 1995 to 2023 reflects a progressive shift from foundational studies to more targeted and policy-driven approaches. Early research (1995–2008) focused on developing clinical guidelines and understanding AMR in specific populations and pathogens, laying the groundwork for subsequent advancements [17]. From 2009 to 2020, attention shifted to antimicrobial stewardship and the education of healthcare professionals, reflecting a growing emphasis on systemic approaches to reduce the burden of AMR [32]. This period also saw greater alignment of educational initiatives with national and international policy frameworks. In the most recent phase (2021−2023), research diversified further, emphasizing specific infections such as respiratory-tract infections and integrating AMR education into broader public health efforts [33]. The COVID-19 pandemic played a pivotal role during this time, highlighting the importance of infection prevention and control measures and accelerating the integration of AMR education into public health strategies worldwide [34].

This bibliometric analysis is subject to several limitations. First, it relies on data from one selected database, which may not capture all relevant publications, especially those in non-English languages or outside indexed journals. Second, the metrics used, such as citation counts, may not fully reflect the quality or impact of the research. Third, the clustering algorithm used to elaborate thematic clusters allows for each word to be included in one cluster only, and this must be considered when analyzing the meaning of thematic maps and thematic evolution. Finally, bibliometric methods cannot provide in-depth qualitative insights into the content or contextual factors influencing the trends observed. Despite these limitations, this analysis offers valuable insights into publication patterns and research focus in the field.

5. Conclusions

The growing emphasis on antimicrobial resistance education reflects a proactive response to the global AMR threat, fueled by stronger national policies, increased funding, and the integration of AMR topics into educational curricula. Current trends show a shift from general awareness to targeted interventions aimed at healthcare professionals, public health initiatives, and community engagement, underscoring the field's adaptability to diverse educational needs. Looking ahead, it is essential to prioritize sustained international collaboration and to align AMR education with policy frameworks to enhance global stewardship and public health outcomes. The ongoing expansion and diversification of AMR education research highlight the importance of interdisciplinary collaboration and innovative strategies for effectively advancing this critical field.

CRediT authorship contribution statement

Sara Farina: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gianluca Fevola:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Andrea Adduci:** Writing – review & editing, Visualization, Methodology, Investigation, Data curation. **Alessandra Maio:** Writing – review & editing, Writing – original draft, Visualization, Investigation, Data curation. **Alberto Lontano:** Writing – review & editing, Visualization, Methodology, Investigation. **Walter Ricciardi:** Visualization, Validation, Supervision, Conceptualization. **Maria Rosaria Gualano:** Visualization, Validation, Supervision, Conceptualization. **Leonardo Villani:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Conceptualization.

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Declaration of competing interest

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

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.onehlt.2025.101120.

Data availability

No data was used for the research described in the article.

References

[1] Antimicrobial resistance, Accessed: Jan. 03, 2025. [Online]. Available, https://www.who.int/news-room/fact-sheets/detail/antimicrobial-resistance.
[2] M. Naghavi, et al., Global burden of bacterial antimicrobial resistance 1990–2021: a systematic analysis with forecasts to 2050, Lancet 404 (10459) (Sep. 2024) 1199–1226, https://doi.org/10.1016/S0140-6736(24)01867-1.
[3] Antimicrobial resistance | EFSA, Accessed: Jan. 03, 2025. [Online]. Available, https://www.efsa.europa.eu/en/topics/topic/antimicrobial-resistance.
[4] N.D. Friedman, E. Temkin, Y. Carmeli, The negative impact of antibiotic resistance, Clin. Microbiol. Infect. 22 (5) (May 2016) 416–422, https://doi.org/10.1016/j.cmi.2015.12.002.
[5] 'Tackling Drug-Resistant Infections Globally: Final Report and Recommendations the Review on Antimicrobial Resistance Chaired by Jim O'Neill', 2016.
[6] DRUG-RESISTANT INFECTIONS A Threat to Our Economic Future, Accessed: Jan. 03, 2025. [Online]. Available, www.worldbank.org, 2017.
[7] WHO Library Cataloguing-in-Publication Data Global Action Plan on Antimicrobial Resistance, Accessed: Jan. 03, 2025. [Online]. Available, www.paprika-annecy.com, 2015.
[8] A. Calvo-Villamañán, Á. San Millán, L. Carrilero, Tackling AMR from a multidisciplinary perspective: a primer from education and psychology, Int. Microbiol. 26 (1) (Jan. 2023) 1–9, https://doi.org/10.1007/S10123-022-00278-1.
[9] C.A. Primeau, J.E. McWhirter, C. Carson, S.A. McEwen, E.J. Parmley, Exploring medical and veterinary student perceptions and communication preferences related to antimicrobial resistance in Ontario, Canada using qualitative methods, BMC Public Health 23 (1) (Dec. 2023) 1–15, https://doi.org/10.1186/S12889-023-15193-X/FIGURES/1.
[10] L. Price, et al., Effectiveness of interventions to improve the public's antimicrobial resistance awareness and behaviours associated with prudent use of antimicrobials: a systematic review, J. Antimicrob. Chemother. 73 (6) (Jun. 2018) 1464–1478, https://doi.org/10.1093/JAC/DKY076.
[11] G. Sharma, et al., Comparing the effectiveness of different approaches to raise awareness about antimicrobial resistance in farmers and veterinarians of India, Front. Public Health 10 (Jun. 2022), https://doi.org/10.3389/FPUBH.2022.837594.
[12] Bibliometrix - Biblioshiny, Accessed: Jan. 03, 2025. [Online]. Available: https://www.bibliometrix.org/home/index.php/layout/biblioshiny.
[13] D.F. Thompson, C.K. Walker, A descriptive and historical review of bibliometrics with applications to medical sciences, Pharmacotherapy 35 (6) (Jun. 2015) 551–559, https://doi.org/10.1002/PHAR.1586.
[14] C. Yuan, et al., Research on antibiotic resistance in Helicobacter pylori: a bibliometric analysis of the past decade, Front. Microbiol. 14 (Jun. 2023) 1208157, https://doi.org/10.3389/FMICB.2023.1208157/BIBTEX.
[15] L. Selva-Pareja, A. Ramos-Pla, P. Mercadé-Melé, A. Espart, Evolution of scientific production on health literacy and health education-a bibliometric analysis, Int. J. Environ. Res. Public Health 19 (7) (Apr. 2022), https://doi.org/10.3390/IJERPH19074356.
[16] J. Carlet, C. Pulcini, L.J.V. Piddock, Antibiotic resistance: a geopolitical issue, Clin. Microbiol. Infect. 20 (10) (Oct. 2014) 949–953, https://doi.org/10.1111/1469-0691.12767.
[17] C.F. Luz, et al., Mapping twenty years of antimicrobial resistance research trends, Artif. Intell. Med. 123 (Jan. 2022) 102216, https://doi.org/10.1016/J.ARTMED.2021.102216.
[18] G. Sun, et al., Antibiotic resistant bacteria: a bibliometric review of literature, Front. Public Health 10 (Nov. 2022), https://doi.org/10.3389/FPUBH.2022.1002015.
[19] F. Farhat, M.T. Athar, S. Ahmad, D.Ø. Madsen, S.S. Sohail, Antimicrobial resistance and machine learning: past, present, and future, Front. Microbiol. 14 (2023), https://doi.org/10.3389/FMICB.2023.1179312.
[20] S. Bertagnolio, et al., WHO global research priorities for antimicrobial resistance in human health, Lancet Microbe 5 (11) (Nov. 2024), https://doi.org/10.1016/S2666-5247(24)00134-4.
[21] W.M. Sweileh, Bibliometric analysis of peer-reviewed literature on antimicrobial stewardship from 1990 to 2019, Glob. Health 17 (1) (Dec. 2021), https://doi.org/10.1186/S12992-020-00651-7.
[22] S. Rogers Van Katwyk, S.L. Jones, S.J. Hoffman, Mapping educational opportunities for healthcare workers on antimicrobial resistance and stewardship around the world, Hum. Resour. Health 16 (1) (Feb. 2018), https://doi.org/10.1186/S12960-018-0270-3.
[23] K.F. Sutton, L.W. Ashley, Antimicrobial resistance in the United States: origins and future directions, Epidemiol. Infect. 152 (Feb. 2024), https://doi.org/10.1017/S0950268824000244.
[24] R.A. Hamilton, B. Lond, L. Wilde, I. Williamson, Understanding the lived-experience and support-needs of people living with antimicrobial resistance in the UK through interpretative phenomenological analysis, Sci. Rep. 14 (1) (Dec. 2024), https://doi.org/10.1038/S41598-024-53814-6.
[25] M. Barchitta, et al., The "Obiettivo Antibiotico" campaign on prudent use of antibiotics in Sicily, Italy: the pilot phase, Int. J. Environ. Res. Public Health 17 (9) (May 2020), https://doi.org/10.3390/IJERPH17093077.
[26] O. Hawkins, et al., Comparing public attitudes, knowledge, beliefs and behaviours towards antibiotics and antimicrobial resistance in Australia, United Kingdom, and Sweden (2010−2021): a systematic review, meta-analysis, and comparative policy analysis, PLoS One 17 (1) (Jan. 2022), https://doi.org/10.1371/JOURNAL.PONE.0261917.
[27] G.Y. Fang, F.H. Wu, X.J. Mu, Y.J. Jiang, X.Q. Liu, Monitoring longitudinal antimicrobial resistance trends of Staphylococcus aureus strains worldwide over the past 100 years to decipher its evolution and transmission, J. Hazard. Mater. 465 (Mar. 2024) 133136, https://doi.org/10.1016/J.JHAZMAT.2023.133136.
[28] L.A. O'Donnell, A.J. Guarascio, The intersection of antimicrobial stewardship and microbiology: educating the next generation of health care professionals, FEMS Microbiol. Lett. 364 (1) (Jan. 2017), https://doi.org/10.1093/FEMSLE/FNW281.

[29] J. Zinsstag, et al., Advancing one human-animal-environment health for global health security: what does the evidence say? Lancet 401 (10376) (Feb. 2023) 591–604, https://doi.org/10.1016/S0140-6736(22)01595-1.
[30] E.L. Gilham, N. Pearce-Smith, V. Carter, D. Ashiru-Oredope, Assessment of global antimicrobial resistance campaigns conducted to improve public awareness and antimicrobial use behaviours: a rapid systematic review, BMC Public Health 24 (1) (Dec. 2024), https://doi.org/10.1186/s12889-024-17766-w.
[31] S. Parveen, N. Garzon-Orjuela, D. Amin, P. McHugh, A. Vellinga, Public health interventions to improve antimicrobial resistance awareness and behavioural change associated with antimicrobial use: a systematic review exploring the use of social media, Antibiotics (Basel) 11 (5) (May 2022), https://doi.org/10.3390/antibiotics11050669.
[32] J. Satterfield, A.R. Miesner, K.M. Percival, The role of education in antimicrobial stewardship, J. Hosp. Infect. 105 (2) (Jun. 2020) 130–141, https://doi.org/10.1016/J.JHIN.2020.03.028.
[33] H. Fletcher-Miles, J. Gammon, S. Williams, J. Hunt, A scoping review to assess the impact of public education campaigns to affect behavior change pertaining to antimicrobial resistance, Am. J. Infect. Control 48 (4) (Apr. 2020) 433–442, https://doi.org/10.1016/J.AJIC.2019.07.011.
[34] K. Walia, et al., How can lessons from the COVID-19 pandemic enhance antimicrobial resistance surveillance and stewardship? Lancet Infect. Dis. 23 (8) (Aug. 2023) e301–e309, https://doi.org/10.1016/S1473-3099(23)00124-X/ASSET/C6A52704-1F06-4ED6-A808-D37D5F66794D/MAIN.ASSETS/GR2.JPG.