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Shaping the future: Current landscape and potential impact of educating children and adolescents on antimicrobial resistance – a systematic review and narrative synthesis

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ABSTRACT

Objectives: To synthesise evidence of antimicrobial resistance (AMR) educational initiatives for school-aged children and adolescents, evaluating global reach, pedagogical theory and impact.

Study design: A systematic literature review and narrative synthesis.

Methods: A systematic search of PubMed, SCOPUS and ERIC to March 2025, supplemented with an online open call to maximise global participation. Educational initiatives explicitly focused on AMR were included. Data extracted covered development, delivery, outcomes, pedagogical approaches, and evaluation. Risk of bias for published studies was assessed using ROBINS-I.

Results: 119 educational initiatives from 44 countries (20 high-income and 24 lower middle-income settings) were included. The most prevalent delivery methods were the creation of lesson plans for educators (40%) or games (43%). The primary stated outcome of 101 initiatives was to improve knowledge of AMR. Individual constructivism (learner-centred) was the most common pedagogical approach. Forty-four initiatives evaluated change in AMR knowledge, all showing an improvement. Thirty were linked to regional educational curricula. Only three initiatives reported AMR-related intended or self-reported behaviour change. No initiatives had measured objective AMR-related outcomes.

Conclusion: AMR-focused educational initiatives for children and adolescents mainly focus on improving knowledge of AMR, not yet extending to enhancement of skills for behaviour change. The review is the first to include an open call for submissions, improving equity in reporting those activities not typically published in academic literature and contributes to the UN General Assembly recommendations of global collaboration and resource sharing for education. Future opportunities include innovation in pedagogy through participatory co-development with teachers and students.

1. Introduction

Antimicrobial resistance (AMR) develops following the evolution of microbes such as bacteria, viruses or fungi, allowing them to evade treatment by antimicrobial agents.¹ The mechanisms for the development of AMR are numerous, including genetic changes that confer the ability to survive in the presence of an antimicrobial drug, target site modifications, and the enzymatic breakdown of antimicrobials.² The

consequences of AMR are grave, with 39 million deaths forecast globally between 2025 and 2050 if we do not alter the current trajectory.³ AMR should be viewed through a “One Health” lens, having significant impacts on agriculture, plant health and the wider environment, in addition to its effect on human health and disease. Cumulative losses due to AMR in livestock are predicted to be at least USD 950 billion between 2021 and 2050.⁴

The use of antimicrobials is absolutely necessary to prevent or treat

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infections across One Health contexts, but inappropriate antimicrobial use is prevalent globally. Reasons for this include lack of public knowledge about when and how to take antimicrobials, poor antimicrobial prescribing and use in veterinary, agriculture and human health (e.g. overuse of broad-spectrum antibiotics), pressure on healthcare, and poor infection prevention and biosecurity allowing infections to spread more easily. Delayed access to care and falsified antimicrobials – that is, lack of access to antimicrobials is also a driver for resistance.⁵

Change is possible, with universal access to high-quality water, sanitation, and hygiene services estimated to prevent 247,800 AMR-associated deaths, equating to prevention of 5.7% of all AMR-associated mortality in LMICs.⁶ Whilst scientific innovation and new drug development is a crucial component in the mitigation of ongoing AMR, without societal behaviour change these new therapeutics will become redundant.^{7–11}

Individual and collective actions regarding infection prevention and antimicrobial use have a key role in preventing the conditions that favour microbial evolution. These behaviours include regular hand-washing, only accessing antimicrobials from trusted sources and when indicated, taking them exactly as directed, and not sharing antimicrobials with others.¹² To truly embed these antimicrobial stewardship behaviours in populations across the globe, adequate understanding of the aetiology and consequences of AMR are essential, ideally early in life as possible.

This promotion of antimicrobial stewardship is supported in Paragraph 51 of the political declaration made at the 2024 United Nations General Assembly (UNGA), and the commitment is made at all levels of education.¹³ The declaration commits member states to integrate antimicrobial resistance modules in primary, secondary and tertiary education, by enhancing targeted efforts through a One Health approach to promote awareness via education, training, and behavioural training methods.¹³ Though children and adolescents aged 5–18 may lack agency over antimicrobial use decisions, educating them about AMR and infection prevention promotes vital advocacy for antimicrobial stewardship.¹⁴ This aims to cultivate a generation actively engaged in reducing AMR, through their own behaviour change, peer-to-peer encouragement, and future championing of stewardship behaviours which can ripple effectively to their family and community.

Current systematic reviews on AMR education are either focused upon the general population (with children and adolescents as a subgroup),^{15,16} limited to one global region¹⁷ or explore the impact of one type of educational intervention, such as gaming.^{18,19} These reviews do not capture many local initiatives in the community setting since their methods and outputs are often under-reported in the academic literature.

This systematic review and narrative synthesis aimed to capture and evaluate AMR educational initiatives across the globe and addresses the following overarching question: How and where have educational initiatives relating to antimicrobial resistance been implemented across the globe, and are they successful in enhancing AMR related knowledge, inspiring behaviour change, or generating health-related impact?

This study is part of a wider programme of work aimed at designing and implementing AMR educational initiatives globally. Complementary to this current study is a Global Consensus document, supported by the Fleming Initiative. This framework, developed by over 70 international experts across education and One Health, outlines guiding principles, overarching themes, and key knowledge areas to enhance existing initiatives, help with the co-design of new initiatives and provide consistency for measuring outcomes and impact.

2. Methods

2.1. Search strategy and selection criteria

A systematic review and narrative synthesis was conducted using a comprehensive search of published peer reviewed literature. PubMed,

SCOPUS and Education Resources Information Centre (ERIC) were searched from the date of origin to March 1, 2025. This was supplemented by online searches, review of grey literature, hand searches of references of included papers and of systematic reviews and an open call for submissions via the Fleming Initiative's social media channels (Until March 31, 2025).

The specific sub-questions guiding this review were:

- Which AMR educational initiatives have been developed for primary and secondary school children and adolescents across the world?
- What are the intended outcomes of these initiatives with respect to AMR?
- Is there any evidence of AMR-related behaviour change as a result of these initiatives?
- What evaluations regarding AMR-related health outcomes have been undertaken?
- What theoretical underpinnings of pedagogy are used within these educational initiatives?
- Is there any evidence of AMR educational initiatives for primary and secondary school children being adopted and scaled, or incorporated into national curricula?

The search strategy was developed using the PECO approach to question formulation.²⁰ Educational initiatives were included if they were aimed at school-aged children and adolescents (5–18 years) and had an explicit focus on AMR. Educational initiatives that were related to hygiene or infection prevention but did not explicitly mention AMR were excluded. There was no limitation on geographical region or language. The full search strategy and inclusion/exclusion criteria can be viewed in [Supplementary File 1](#).

Online hand searches were conducted in triplicate and independently by KG, AA and COM for full coverage and to reduce bias. Screening of titles, abstracts and full text were completed by at least two reviewers from a team of four (KG, MD, COM, AA) independently using Covidence systematic review software. Discrepancies during screening were resolved by consensus or referred to a third reviewer. This systematic review was conducted in accordance with the PRISMA guidelines²¹ and registered prospectively on PROSPERO (CRD42025637846).

2.2. Data analysis

Once identified for inclusion, the full texts or resources for all educational initiatives were reviewed. Reviewers (KG and MD) extracted the following data points where available: date of educational initiative, country/location of development, target age range, location of delivery, intended outcome of educational initiative, method of development, evidence of pedagogical approach, method of evaluation, measured outcome, evidence of adoption or scale and evidence of link to the region's national curriculum. For standardisation of data extraction and synthesis across the reviewers and initiatives, a desired outcome was only included if it was a clearly stated aim, objective or outcome of the initiative, not one that was inferred by the review team. Reviewers met weekly to discuss the extraction process to improve accuracy and concordance between April and July 2025.

The majority of data extraction points were qualitative in nature and were tabulated and reviewed for similarities. A narrative synthesis was conducted for the following: type of educational initiative, the stated or pre-defined outcome of the educational initiative and the evidence of pedagogical approach. Four pedagogical approaches were used for coding: Liberationism (student voice at centre, teacher as the learner);²² Behaviourism (teacher-centred);²² Individual constructivism (learner-centred, with students as active learners);²² Socio-constructivism (students and teachers working together).²³ Full description of the pedagogical styles can be seen in [Box 1](#).

All included initiatives were reviewed for a quantitative evaluation of their impact and reviewed for suitability for meta-analysis. The

Box 1: Types of Educational Pedagogy

Liberationism (student voice at centre, teacher as the learner).

Drawing from Paulo Freire's work, where students are empowered as active participants and each student can take on the role of an educator. This pedagogy transforms the classroom into a democratic space where students' life experiences and contributions are valued, and learning is connected to real-world issues.

Behaviourism (teacher-centred).

In this pedagogy, external forces and reinforcement is used as the mechanism to promote behaviour change. This is the basis for traditional lecture-style teaching method, using positive reinforcement to encourage students and create a productive learning environment.

Individual constructivism (learner-centred, with students as active learners).

This is based on students actively building knowledge based on prior experiences, promoting contextualised and project-based learning and inquiry which increases motivation and performance.

Socio-constructivism (students and teachers working together).

This pedagogy views learning as a social and cultural process where knowledge is built through interaction and shared experiences. This approach uses collaborative methods like cooperative learning to improve academic performance and strengthen teamwork.

planned approach was to determine and calculate an effect size for each study. Data from eligible studies was planned to be pooled with a summary and confidence interval (95%) calculated. Heterogeneity between the studies was planned to be assessed with Cochran Q and Higgin I² tests.

As it was anticipated that most studies would be qualitative with intervention evaluation non-randomised, the ROBINS-I tool²⁴ was selected to assess the risk of bias (ROB) for published studies across the seven domains leading to a “low”, “moderate”, “serious” or “critical” risk of bias being assigned to each one.

3. Results

The yield from electronic databases was 2734 articles plus 8 identified through reference searches/previous systematic reviews, 18 initiatives identified through online searches and 46 initiatives submitted to the open call on Fleming Initiative's social media. 198 articles met the inclusion criteria for full text review. The absence of a clear AMR focus, or initiatives that were children/adolescent focused but aimed at parents/carers/healthcare professionals were the main reasons for exclusion (Fig. 1).

The final review included 119 initiatives, 55 of which were peer reviewed academic papers. Initiatives were from 44 countries - 20 high-income and 24 lower middle-income settings (Figs. 2 and 3, and Supplementary File 2). Ninety-two of the articles referred to standalone educational initiatives. Two educational programmes were identified, e-Bug and Small World Initiative/Tiny Earth, each with several papers on the different educational initiatives within. Twenty-five^{25–49} published papers related to the e-Bug programme,⁵⁰ including its development, implementation in different countries, and outcomes. The e-Bug programme is operated by the UK Health Security Agency, with a focus on AMR and infection prevention. It has partnered with over 27 countries, across Europe, Saudi Arabia, Palestine, and Turkey with resources available in 23 different languages. Six^{51–56} published papers focused upon evaluating the Small World Initiative and Tiny Earth, which are consolidated education programmes developed in USA using a crowd-sourcing strategy to address AMR.^{53,57} Geographically, the UK had the most, with 48 included papers^{25,26,28,29,31–36,42–49,53–82} Overall, most initiatives were developed locally by individual study teams and 23^{25,31,32,36,53,54,60,67,69,88–101} initiatives described methods of co-creation or collaboration with the public, students or educators. Intended participants by age ranged from those designed for the entire school (20%), ages 4–12 (23%), ages 12–18 (27%) but some of these

focused on just one or two years and 30% did not state the age range. A summary of the study characteristics are included in Table 1. The full study characteristics are included in Supplementary File 3. All review outcomes are included in Supplementary File 4.

The initiatives were often multi-component, categorised with a primary and additional type. Games (either digital or analogue) were a component of 41 initiatives.^{25,26,28,29,31,32,35,37,38,40,41,43,46–49,51,54,58,61,63,66–68,72,77,78,81,84,90,93,94,98,102–109} Many initiatives (40) were “Lesson Plans/Resources for teachers”,^{31,32,36–41,48,49,59,62,65–67,69,70,74,92–95,98,108,110–115} with the remaining categories (Film/Video media, Interactive activities, Physical Resources, Delivered lesson/seminar), evenly distributed.

Across initiatives “Improve knowledge of AMR” was the most common (101 initiatives) aimed primary outcome. “Improving Antimicrobial stewardship” was listed as a secondary goal in 31 initiatives.^{45,46,51,55,63,74,78,81–85,87,90,94,95,99,101,102,105,107,116–125}

“Advocacy” was the least cited objective overall, never a primary objective but was a secondary or tertiary objective in 25 of the initiatives.^{32,51,60,79,90,91,96,97,105,107,108,113,117,119,122,126–135}

Thirty-three^{27,30–32,34,40,42–44,46–48,52,53,55,56,58–61,64,65,88,89,116,117,126–128,136–139} published initiatives objectively evaluated a change in

AMR-related knowledge following their intervention, with the majority comparing this to a baseline value. These studies assessed awareness and knowledge related to antimicrobial resistance and antibiotic use, exploring understanding of when and how antibiotics should or not be taken, and the risks of misuse. Aspects which might shape behaviour of antibiotic use that were captured include: whether to stop antibiotics early, share antibiotics, use leftover antibiotics or obtain them without a prescription. Eleven studies also included knowledge of microbes, covering concepts such as healthy versus harmful bacteria and the role of the gut microbiome, as well as awareness of vaccination, infection spread, and safe medication storage.

Surveys, questionnaires, and knowledge assessment were the most common methods of evaluation, along with oral and written feedback and individual and group discussions. Feedback on engagement and enjoyability was a metric utilised in papers evaluating digital and analogue games, and interactive activities. All of the initiatives with feedback demonstrated an improvement in AMR knowledge in at least one parameter. Eleven^{71,72,80,81,95,99,105,108,119,130,135} unpublished initiatives demonstrated an improvement in AMR knowledge, with a further two^{101,140} stating a future intention to evaluate change in AMR knowledge. No other AMR-related health outcomes (such as change in infection or resistance rates) were evaluated as a direct result of the

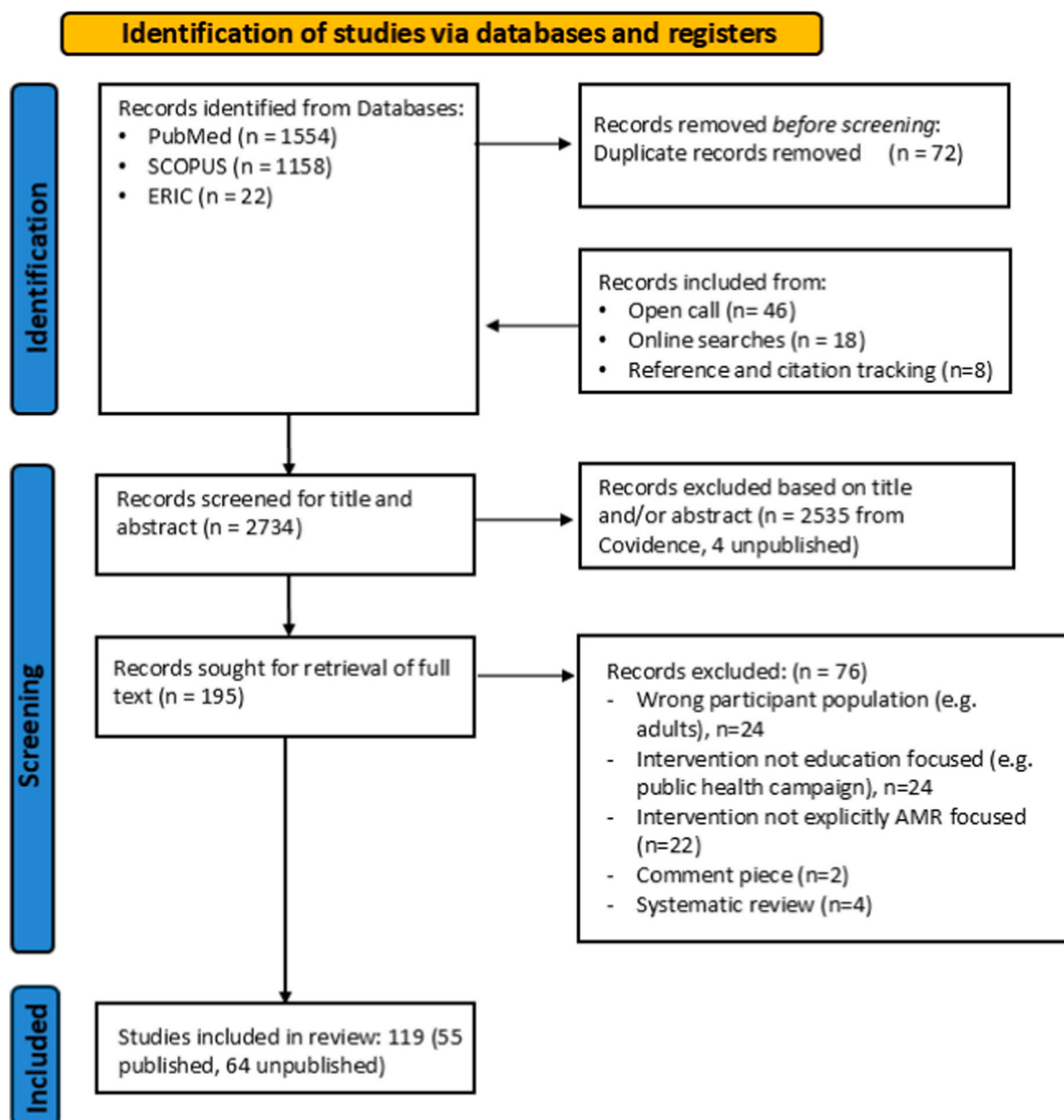


Fig. 1. PRISMA - Study selection flow chart.

included educational initiatives.

Many stated “Promoting behaviour change” as an intended outcome of the initiative, only three explored or presented evidence of AMR-related changes in behavioural intent or real-world behaviour change. Of these three initiatives that did report this data, one published study³⁰ explored self-reported behavioural intent following the initiative, finding that 54% of participants said they would take antibiotics only when required, and 69% would wash their hands. Real world behaviour change was observed in another published study from Moldova which utilised peer-led education and students self-reported a 34% reduction in antibiotic use.⁹¹ The third initiative was unpublished from an Ugandan pilot of the UKHSA’s Antibiotic Guardian campaign, with 86% of children pledging to tell families what they had learnt and 95% stating they would only take antibiotics when indicated.¹⁴¹

Categorisation by pedagogy was possible for 56 initiatives, with individual constructivism (learner-centred, with students as active learners) being the most prominent style, seen in 44 initiatives^{25–33,35,42,43,46,47,51,52,58,59,61,63,66,69,70,78,88,89,91,92,94}

,^{103,104,106,108,113,117–119,126,128,132,134,136–138} A wide range of educational approaches were employed within this category, including peer education and applied active learning,³³ problem-based learning³⁵ and a citizen science model.⁶²

Behaviourism (teacher-centred) was employed in eight initiatives,^{71,95,96,110,111,126,130,142} four^{75,93,105,128} employed social constructivism (students and teachers working together), and only two adopted a liberationism^{122,127} (student voice at the centre, teacher as the learner) approach.

Seventeen initiatives^{69,71,73,76,77,81–86,89,92,99,143–145} incorporated the usage of social media, campaigns, or exhibitions for AMR knowledge transfer outside of traditional education. Videos on websites such as YouTube were used in 9^{69,73,76,77,92,99,143,145} initiatives, while others included the use of social media in sharing resources and surveys. Cities Birmingham⁷¹ and Leeds⁸¹ in the UK partnered with their local NHS Integrated Care Boards to launch city-wide campaigns with traditional print media, and universities and museums across countries have held exhibitions to improve the awareness of AMR to children and the public

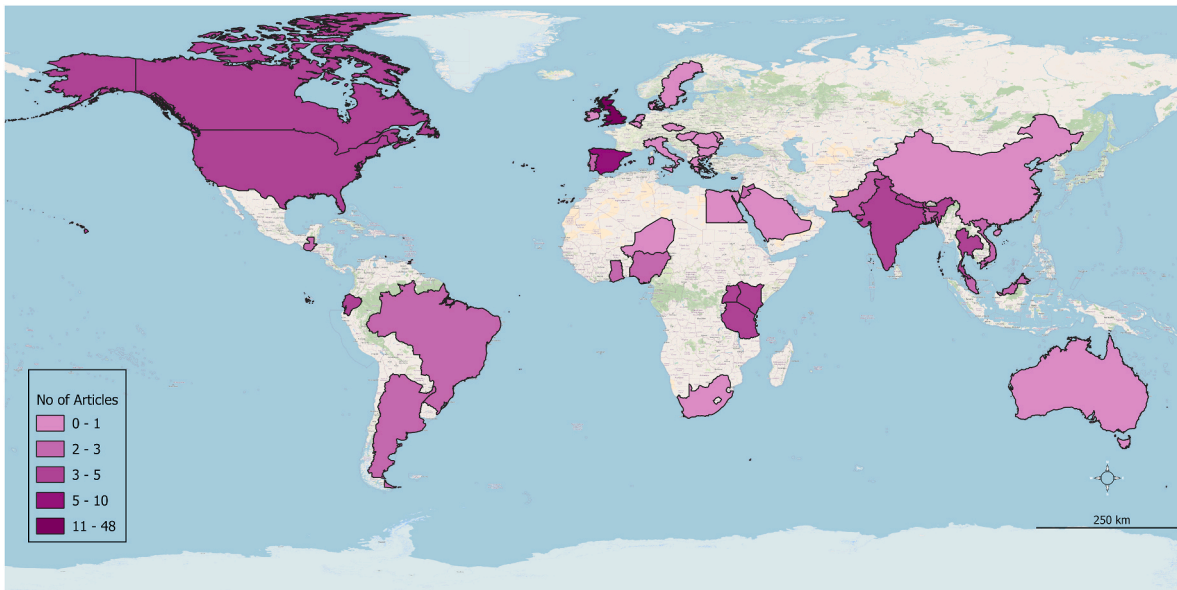


Fig. 2. Map showing number of articles in each of the 44 countries.

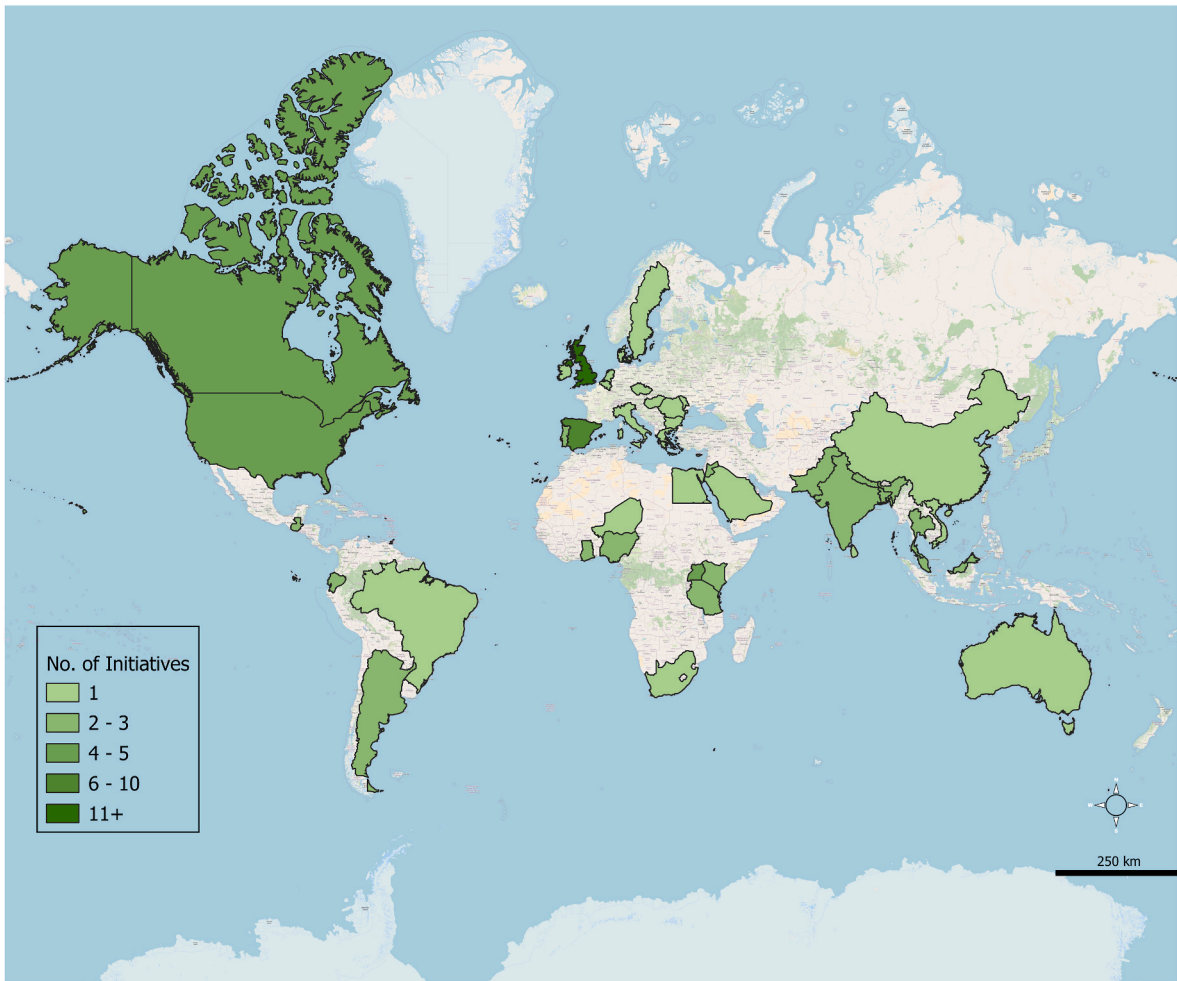


Fig. 3. Global spread of initiatives across 44 countries.

Table 1
Summary of study characteristics.

Parameter		Published (%)	Unpublished (%)	Total
Number of papers		55 (46%)	64 (54%)	119
Type of Initiative	Games (Digital or Analogue)	26 (60%)	17 (40%)	43 (36%)
	Interactive Activities	19 (56%)	15 (44%)	34 (29%)
	Physical Resources	6 (25%)	18 (75%)	24 (20%)
	Film/Video Media	3 (18%)	14 (82%)	17 (14%)
	Lesson Plans/Resources for Teachers	14 (36%)	25 (64%)	39 (33%)
Type of Pedagogy	Delivered Lesson/Seminar	22 (67%)	11 (33%)	33 (28%)
	Individual Constructivism	30 (68%)	14 (32%)	44 (37%)
	Behaviourism	0 (0%)	7 (100%)	7 (6%)
	Liberationism	1 (50%)	1 (50%)	2 (2%)
	Socio-constructivism	0 (0%)	3 (100%)	3 (3%)
Source	Information N/A	24 (38%)	39 (62%)	63 (53%)
	Formal Database	54 (98%)	1 (2%)	55 (46%)
	Hand Searches	1 (6%)	17 (94%)	18 (15%)
	Open Call	0 (0%)	46 (100%)	46 (39%)
Influence on Curricula Adoption and Scaling		21 (72%)	8 (28%)	29 (24%)
	Adoption or Scaling	20 (67%)	10 (33%)	30 (25%)
	Online or Downloadable content	4 (24%)	13 (76%)	17 (14%)
	Planned scaling	3 (60%)	2 (40%)	5 (4%)
Stated Intended Outcome	Improve knowledge of AMR	53 (48%)	57 (52%)	110 (92%)
	Improve Antimicrobial Stewardship	13 (26%)	27 (54%)	50 (42%)
	Infection Control and Prevention	22 (49%)	23 (51%)	45 (38%)
	Promote Behaviour Change	25 (64%)	14 (36%)	39 (33%)
	Advocacy	10 (40%)	15 (60%)	25 (21%)

in an accessible manner. However, none of these initiatives measured behavioural change, and only one initiative assessed behavioural intent.⁸¹

Twenty-one^{28,31,35–39,41–44,46–48,55,58,60,62,67,116,128} published initiatives and eight^{75,78,80,106,115,120,121,132} unpublished initiatives described a clear influence of their national curriculum on the development of the initiative. None reported influencing national curricula in turn. Thirty^{25,28–31,35–37,41,42,48,51,53–56,66,67,72,74,79,81,93,98,105,107,126,133,139,140} initiatives demonstrated evidence of wider adoption or scaling, with 17^{43,44,46,58,68,84,94,95,103,106,111,113,114,118,121,130,142} giving online and downloadable open access, and five more planning to do so.^{59,89,90,97,119}

Results of the ROBINS-I tool for the published studies (Supplementary Files 5 and 6), found that for overall risk of bias, 27^{26,36–42,44,46,52–56,58,60,67,88–90,117,127,128,137–139} initiatives were judged to be at moderate risk, 27^{25,27–35,43,45,47–49,51,59,61–66,91,116,126,136} at serious risk and 1¹²⁹ of critical risk. This risk of bias judgement reflects the fact that no educational interventions were evaluated in a randomised trial, often with self-reported outcome measures.

The variety of instruments used to measure AMR knowledge outcomes across the initiatives were heterogeneous, and as such, these data were not suitable for meta-analysis.

4. Discussion

This systematic review presents a comprehensive overview of the current educational initiatives across the globe that seek to address AMR, with a focus on their development, delivery, and measured outcomes.

There are key contributions arising from this review, and the search method employed enhanced the capture of initiatives originating from LMICs. AMR education is taking place across the globe, with 44 countries representing high, middle, and low-income settings.

Beyond the e-Bug programme of work,⁵⁰ whose global impact and presence is significant, there was limited evidence of scaling and adapting initiatives within or across countries, despite many initiatives being similar in both nature (such as games, or lesson plans for teachers), and intended objectives (typically improving knowledge of AMR). There is, therefore, scope for increased collaboration between global

regions, sharing ideas and educational resources to mitigate costs of (re) developing initiatives ground up. Engagement of community leaders, educators, and policy makers, is important to ensure communication, collaboration and sustained resource availability.

While change in AMR knowledge was captured and improved (28% of initiatives), only 3 additionally reported evaluated changes in intended behaviours around antimicrobial stewardship. There is therefore significant opportunity to improve the robustness of the evaluation of AMR-focused educational initiatives and should extend to consequent antimicrobial use, resistance rates and infection rates. The ability to demonstrate the impact of educational activities in such a manner supports the case for ongoing investment in AMR education at a policy level.

23 out of the 42 initiatives that included a survey or questionnaire as part of their assessment contained questions related to using antibiotics for colds, the flu, or other viral infections. These surveys are included in Supplementary File 7. The online platform e-Bug also contains resources focused on preventing antibiotic use for non-bacterial infections. Research in China, further downstream, of university students,¹⁴⁵ finds that awareness of AMR did not translate to prudent antibiotic use, reiterating the importance of education around appropriate antimicrobial use from a young age.

There was only one initiative⁹¹ that explicitly addressed reducing antibiotic use for cold and flu. This study, based in Moldova, targeted 12–13-year-olds and their parents. Using a student peer-led programme, this initiative showed improvements in knowledge of AMR and beliefs surrounding antibiotics of both students and their parents through pre-post intervention surveys.

Peer education is a feasible and effective model, supported by six initiatives^{33,34,44,45,91,127} including e-Bug. Peer educators demonstrated personal development, including increased confidence, communication, and leadership skills, alongside improved AMR knowledge. Students showed improvement in knowledge, which, as one paper⁹¹ showed, may affect parental attitude toward antimicrobials and AMR. Three initiatives^{46,91,127} included parents/caregivers; however, long-term impact analysis was not possible with only immediate post-intervention knowledge assessment.

This review also highlights an opportunity for enhancing and building in co-design of initiatives with students and teachers (currently only reported in 19% of initiatives). Using such participatory methods to

develop educational initiatives improves the likelihood of children and adolescents engaging with and learning from the initiative as it was created with them, for them. This approach has been successful in other similar educational settings, not only enhancing learning and wellbeing, but also allowing students to understand educators' perspectives, some of which are outlined below. Only around one third of initiatives report being linked to or influenced by curricula objectives, but none are embedded in turn within the curricula. Participatory development of initiatives including policy makers and senior educators for alignment with curricula would facilitate integration with mainstream education. In terms of pedagogy learner-centred approaches were highly prevalent and are perceived as a positive strategy by both learners and educators. However, identification of pedagogy theory was only possible for 56 initiatives which may be reflective of the disciplinary focus of the publishing journals (16 medical and pharmaceutical; 6 public health, 2 gamified health research, 2 educational, 3 scientific, 1 veterinary medicine, 1 engineering) or the lack of consideration during initiative development.

Our findings show that very few programmes have undergone robust outcome evaluation. As a result, the current evidence base is insufficient to confidently determine which specific approaches are most effective.

The findings of this review align with previously published reviews, showing that gaming can be an effective method of engaging children and adolescents¹⁹ and that knowledge and attitudes to AMR were the most frequently evaluated outcomes.¹⁷ A 2020 scoping review explored the impact of public education campaigns on AMR-related behaviour change, finding that many interventions lacked theoretical underpinnings and did not address sustained behaviour change,¹²² themes which are reflected in this review. Social media can be a useful tool for public health messaging, however there are also drawbacks to consider, including placing of information among the plethora of misinformation.^{146,147} Additionally, all privacy, and potential moral, ethical, and legal consideration must be made.¹⁴⁸ There is also a current global push towards restricting social media use for children and adolescents. Australia's Online Safety Amendment (Social Media Minimum Age) Act 2024 prohibits children and adolescents under-16 to hold accounts on certain social media applications, including YouTube. Investment in social media formats need to take account of this changing policy landscape. The challenges and opportunities of achieving lasting behaviour change through education is not unique to AMR. This is evidenced by systematic reviews across other public health domains, including HIV and sexually transmitted infection prevention, healthy weight promotion, and smoking prevention.

A systematic review of initiatives in Sub-Saharan Africa¹⁴⁹ showed that school-based interventions can successfully improve adolescents' knowledge and attitudes towards HIV and sexually transmitted infections. Further studies in Sub-Saharan Africa¹⁵⁰ demonstrated that such education has the potential to translate into positive behavioural outcomes, particularly in promoting the use of contraceptives.

Global systematic reviews^{151,152} concluded that school-based and digital interventions have the potential and can be effective in preventing overweight and obesity in children and adolescents. Notably, these reviews face a similar limitation also present in our AMR review - the unreliability of unpublished articles and lack of robust evaluation. Even within evaluated articles, the effectiveness was mixed, prompting calls for more long-term, multi-faceted interventions embedded into the curricula, and involve families and the wider community.

Evidence from smoking prevention in high and low-income settings^{153,154} demonstrates that programmes focused solely on knowledge acquisition have been largely ineffective, whereas those fostering interactive social and life skills show significant benefits. Crucially, evidence synthesis from low- and middle-income settings explicitly reinforces these findings.¹⁵⁵

This collective body of evidence reinforces the present study's central focus that the pedagogical design of AMR initiatives is a critical determinant of their success, and that their effectiveness beyond knowledge

of a health priority is needed to shape behaviours.

The first limitation of our current review arises from the inevitability of missing those local initiatives which are not represented/captured online. Second, since our inclusion criteria required explicit AMR mention, some AMR-related initiatives, such as handwashing only would be excluded here. Third, we did not externally validate if programmes had been linked to national curricula, and finally, there were gaps in data extraction and synthesis since we use all forms of reporting in addition to peer reviewed articles, which may have introduced bias.

Studies assessing longer term impact were not available for the educational initiatives identified in this current study and has been highlighted as an action when co-developing and implementing initiatives with country partners.¹⁵⁶

There are many opportunities for future work as a result of this review. The Quadripartite Working Group for Youth Engagement on AMR developed the Youth Manifesto for the UNGA 2024 High-Level Meeting, in which they call for the direct engagement and involvement of youth in all educational activities and materials, rather than simply seeing them as passive recipients and down-stream beneficiaries.¹⁵⁷ A key commitment in the political declaration made at the 2024 UNGA was to improve antimicrobial stewardship through education. We demonstrate the potential for increased communication and collaboration between educators, community leaders and policy makers to both coordinate and share resources, facilitate scaling of initiatives across global regions, and work to align and incorporate AMR into national curricula. This work could be aligned to the Global Action Plan on AMR. As an example of National Actional Plans (NAP) on AMR, the UK NAP (2024-2029) sets out a commitment (number 2.2) on the use of educational settings to meaningfully present infection, prevention and control, infection management, and AMR to empower young people and encourage lasting change. An associated broader target in the UK NAP (Target 2a) is to increase the knowledge of AMR in the public and healthcare professionals by 10% by 2029, compared to the 2018 and 2019 baselines.¹⁵⁸ For those developing educational initiatives, there should be a focus on increased academic evaluation of real-world health outcomes, linking the deployment of educational initiatives to local and regional health datasets on outcomes such as antimicrobial use. It would also be of interest to evaluate the difference in various learning styles and delivery mechanisms on research outcomes, such as the impact of learner-centred initiatives, or those delivered via digital media. Use of other innovative approaches such a digital deliberative polling could enable reach and follow up across school years.¹⁵⁹ Investing in AMR education is an essential part of a broader, one health-focused AMR mitigation strategy,¹⁶⁰ and this review demonstrates the breadth of work taking place across the globe in order to realise this goal. The intention is for this work to be a "living review", with regular review and updates to incorporate new and previously missed initiatives.

Ethical statement

Ethics approval was not required for this systematic review.

Data sharing statement

The authors confirm that the data supporting the findings of this study are available within the supplementary files.

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Declaration of competing interests

None declared.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.puhe.2026.106194>.

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