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A comprehensive scoping review of global educational strategies and outcomes in aedes-borne disease control

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Abstract

Background Aedes mosquito is the primary vector of emerging or re-emerging arboviruses that threaten public health worldwide. Many efforts have been made to develop interventions to control the Aedes mosquito. This scoping review was conducted to identify the nature and scope of educational interventions to prevent and control diseases transmitted through the Aedes mosquito. The findings can be used to evaluate, compare, and develop appropriate control strategies.

Methods The present scoping review was conducted in 2023 and used Arksey and O'Malley's approach, which involves five key stages. To search for academic papers, PubMed, Web of Science, Scopus and ScienceDirect databases were used with a combination of keywords about Aedes mosquitoes, educational interventions, and disease prevention and control. The search was not limited by the publication date, yet only included studies published in English. Studies were included that reported the educational interventions about Aedes mosquito control at the community or organizational level. The screening of papers was done based on the PRISMA-ScR guideline. Excel 2019 was used for data analysis.

Results Initially, 3,172 papers were extracted, and after screenings and reviews, a total number of 45 final papers were selected. The studies focused on educational interventions. Twenty interventional studies were at the organizational level and 25 at the community level. The latter was the most commonly used strategy. Interventions using educational approaches have achieved sustainable results. Out of the forty-five studies, twenty-one were assessed to have a low risk of bias.

Conclusions The present scoping review evaluates the effectiveness of educational interventions at various community levels for controlling Aedes-borne diseases, emphasizing the need for multidisciplinary collaboration. Controlling Aedes mosquitoes using education and attracting the community's participation is an effective approach to reduce diseases transmitted through Aedes. The development of education at different levels of the community, such as educational and occupational environments, can play a role in the effectiveness of societal education and can be more cost-effective. Maintaining the effect of this approach is challenging because it requires multi-sector

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and multidisciplinary team participation and active community engagement over the long term. Further research is required to explore the removal of barriers to the implementation of educational interventions and the consistency of effects.

Keywords Aedes, Control, Education, Intervention, Review

Text box 1. Contributions to the literature

- This review uniquely synthesizes the global landscape of educational interventions against Aedes-borne diseases, highlighting innovative strategies and gaps in the current research.
- This review highlights the importance and effectiveness of campaigns and social networks in educational interventions at the community level.
- This review highlights the importance of using theoretical and practical training as workshops at the organizational level.

Background

Invasive species of the Aedes mosquito are a source of increasing concern due to their ability to spread to new lands and widely transmit various human viral diseases, such as dengue fever, Zika, chikungunya, yellow fever, and Japanese fever [1]. These diseases can severely affect health. People and human societies have been limited to tropical regions for a long time; however, with the spread of mosquitoes in other regions and the widespread movement of goods and people around the world, it has quickly spread to temperate regions as well [1, 2]. In 2022, the dengue virus was present in 129 countries—even as far south as France in Europe—and has put about half the world's population at risk [3]. It is estimated that the dengue virus infects 390 million people annually, of which 96 million (25%) show clinical symptoms [4].

The burden of diseases caused by the Aedes mosquito is increasing worldwide. A critical factor in preventing the spread of local outbreaks clearly involves the readiness of the public health system to act and respond after detecting early clinical cases [5]. In 2019, when some countries were facing a severe epidemic of dengue fever and the emergence of other arboviruses such as Chikungunya and Zika was recorded, the World Health Organization (WHO) made a strategic plan to deal with re-emerging arboviruses with an epidemic potential known as the Global Arbovirus Initiative on March 31, 2022. The aim was to provoke global alarm against the epidemic risk of arboviruses and the potential threat of pandemics, and it also suggested a list of priorities for measures that countries and regions can take to prepare for the next arbovirus outbreak [6].

As an integrated strategic plan, the Global Arbovirus Initiative aims to challenge the emerging and re-emerging arboviruses that can turn into a pandemic with a focus on control, risk, prevention of global spread, preparation, diagnosis and reaction, and gathering a group of partners. The plan is a cooperative attempt by the World Health Emergencies Program, the Department of Control of Neglected Tropical Diseases, and the Immunization, Vaccines and Biologicals Department [7].

In particular, arboviruses are transmitted mainly by female Aedes aegypti mosquitoes and sometimes by female Aedes albopictus mosquitoes [1, 8]. The abundance of two species of Ae. aegypti and Ae. albopictus is generally higher in wet seasons. However, in some areas, water storage plays an important role in the development of immature mosquito habitats and population size, especially during the dry season. Therefore, dealing with water storage containers with larvicides or covering containers under insecticide treatment can be an effective control intervention [9]. Aedes albopictus is adapting to urban environments and is more common in some areas than Aedes aegypti due to its ecological flexibility allowing for an exploitation of a wider range of habitats [9]. Therefore, due to human mobility and urbanization, there is a risk of aggravating the local spread of arbovirus [6]. The increase in trade practices in different parts of the world as well as climate changes facilitates the global spread of this mosquito [10–12].

To control the spread of infections transmitted through Aedes, certain measures are taken with a focus on humans as mosquito hosts, interactions between humans and mosquitoes, and specifically interventions on Aedes mosquitoes [13]. These techniques include the use of chemicals [14] and destroying the larvae's habitat [15, 16]. The aforementioned strategies often lack educational components, which limits their effectiveness. Interventions such as indoor residual spraying (IRS), insecticide-treated nets (ITNs) and larval source management can reduce the vector population. However, they do not always lead to sustainable behavior change in communities [13, 17].

Educational interventions are critical to ensure people understand the importance of vector control and engage in protective behaviors such as eliminating mosquito breeding sites. Moreover, such interventions can be adapted to the local and cultural characteristics of the region. Otherwise, communities may not fully participate in control efforts or adopt conservation behaviors in the short run [17, 18]. The community-based educational intervention strategies for Aedes mosquito control used in different countries entail community participation [19]. The above-mentioned interventions that are often

reported to be successful are workshops and educational campaigns, social mobilization with local partnerships [20], community education for age groups such as children and the elderly [21, 22], and the media [23]. These strategies are particularly successful in low- and middle-income countries, where it may be difficult to afford insecticide-based interventions [24].

The epidemic risk of diseases transmitted by the Aedes mosquito reminds us of the need for preventive interventions. Additionally, we need to employ Aedes mosquito control strategies. Therefore, educational interventions at different levels become important. Most review studies have focused on non-educational interventions based on entomological indicators, habitat improvement, and control, and vector reduction [25, 26], or have been limited to educational interventions in a specific area [27]. Thus, there is a need for more investigations with an emphasis on educational interventions in different communities in this regard, and this study was conducted to explore the nature and extent of educational interventions to prevent and control diseases transmitted through the Aedes mosquito.

Materials and methods

Design of study

The present scoping review is based on a framework proposed by Arksey and O'Malley, which recommends that a review to take five steps [28, 29]: (1) identifying the research question, (2) identifying relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing, and reporting results.

Identifying research questions

The main theme of the present scoping review is Aedes mosquito control interventions based on implementing educational programs, such as health education and health promotion, community participation, media campaigns, and educational workshops. The main research question was "What are the characteristics and results of the education-based interventions for the prevention/control of diseases transmitted by the Aedes mosquito?"

Two key objectives were defined as follows:

1. Identification of educational interventions at the community level for the prevention/control of diseases transmitted by Aedes mosquitoes.
2. Identification of educational interventions at the organizational level for the prevention/control of diseases transmitted by the Aedes mosquito.

Identifying relevant studies

In this scoping review, we examined the extracted studies and indentified those based on health education and health promotion, community participation, media campaigns and educational workshops as relevant to the research question. After conducting a preliminary literature review we selected keywords (a combination of AEDES, training, education and interventions), and searched four databases: Web of Science, PubMed, Scopus, and ScienceDirect. The keywords, based on relevant Medical Subject Headings (MeSH), were used to conduct the search.

The eligible studies included: (1) those in which the interventions were based on the implementation of educational programs, such as health education and health promotion meetings, community participation, media campaigns, and educational workshops; and (2) those that considered the effects of educational interventions on increasing knowledge, attitude and performance (KAP), reducing pupae in the household population, decreasing the number of infected households, and implementing environmental adaptations such as reducing mosquito breeding sites.

The exclusion criteria were: (1) interventions that included the use of insecticides, larvicides, and biological control measures without implementing educational programs; (2) cross-sectional studies, descriptive articles, review articles, and systematic meta-analyses that did not include an educational program; and (3) conference papers, letters to the editor, editorials, and commentaries. Furthermore, all full-text studies were in English, and there was no specific time limit. To improve the search sensitivity, the logical operators "OR" and "AND" were used. The EndNote reference manager was used to manage the retrieved references and identify duplicates. The finalized search strategy for the scoping review is presented in Table 1 in the Appendix.

Study selection

The study selection was conducted by two reviewers independently, and disagreements were resolved in a panel discussion of the research team. In the first stage, the titles and abstracts of studies were screened, and in the second stage, the full texts were screened. Data extraction was performed by the two reviewers. The following variables were considered during data extraction: setting of the study, design of study, methodology, demographic information, intervention, and outcomes. The reviewers discussed ambiguous issues until consensus was reached, or a third reviewer was consulted to resolve disagreements. The results of this scoping review include case-control studies, randomized and non-randomized trials, controlled trials, and impact evaluations that have been published in reputable journals. Studies were selected according to their focus on educational interventions for controlling Aedes-borne disease. They were checked for relevance using a structured quality

evaluation framework. To assess all interventional studies, the Cochrane Collaboration Risk of Bias was used (Appendix). The Cochrane Collaboration Risk of Bias Tool scale is comprised of 12 items to evaluate the studies for their internal and external validity. The 12 items were assessed and rated in the review. A score of 1 was assigned for items rated as 'yes', whereas 0 was assigned for 'no', 'unclear', or 'non-applicable'. The degree of bias for each category and each study was considered as either 'high risk' or 'low risk'. Each criterion was of an equal weight or similar value. The percentage of the maximum value comprised the total score. Studies which obtained scores above the mean score had a low risk of bias, whereas studies with a mean score lower than the mean value indicated a high risk of bias [30]. The reference lists of studies was also checked to identify additional relevant studies.

Charting the data

Based on the eligibility criteria, the final studies were selected. Data related to the prevention and control of Aedes-borne diseases were extracted and included in a data extraction form using Microsoft Excel 2019. The first author's name, country, published year, type of study, participants, level of intervention, intervention, and outcomes were extracted and charted in the data extraction form. Two members of the research team implemented the charting process simultaneously [31]. The chart displays the characteristics of the included studies based on the data extracted.

Collating, summarizing, and reporting the results

In this stage, three researchers independently integrated and summarized texts to answer the research question. They reviewed and organized the data extracted from the studies initially into a table of codes with appropriate labels, such as educational campaigns, workshops, and interventions at the community and organizational level. The initial codes were integrated into the final codes. The themes were reviewed, refined, and named, resulting in the identification of educational interventions at the community and organizational levels.

Results

A total of 3,172 studies were identified by the reviewers in the initial search. After removing the duplicates ($n=133$), 2,658 studies that did not match the research question were excluded after reviewing the titles and abstracts, and 381 studies were screened based on the inclusion criteria. In the next step, after reading the full texts of the studies and carefully examining the interventions, 336 studies were removed based on the exclusion criteria and non-implementation of educational interventions. Studies were reviewed, and those that were not based on educational programs at the community and organizational levels were excluded from the investigation. Figure 1 shows the flow chart of the selection process. A total of 45 studies were included in the scoping review. The characteristics of the included studies are presented in Table 1.

Charting the data

Here are the features of the academic papers. A search of databases was conducted according to the PRISMA-ScR (Fig. 1) [32].

Figure 1. **Flow chart of literature search for education-based interventions for Aedes-borne disease control (1992–2022) according to the PRISMA-ScR**.

Risk of Bias

The research articles included in this scoping review were assessed for risk of bias [22, 33–76]. In the Appendix, Table 2 summarizes the risk of bias and the authors' assessments regarding each risk of bias. The average score of the 45 reviewed studies was 5.48. Studies with a total score of 5.48 or higher were rated with low risk of bias. Twenty-one studies were rated with low risk of bias [22, 34, 37–39, 41, 45–47, 50, 51, 53, 57, 58, 60, 64, 65, 68, 70, 71, 76], while the remaining 24 studies were ranked as having high risk of bias [33, 35, 36, 40, 42–44, 48, 49, 52, 54–56, 59, 61–63, 66, 67, 69, 72–75]. A total of 41 studies mentioned participant characteristics [22, 33, 34, 36–39, 41–47, 49–62, 64–76], and 22 studies mentioned participant retention rates of 70% or higher [33, 34, 40–43, 45–47, 50–53, 57–60, 65, 66, 68, 70, 75]. Forty-four studies described the intervention, and only one study did not describe the interventions in detail [43].

As shown in Fig. 2, Colombia had the highest number of studies included in this scoping review, and in general, most studies were conducted in South America and Asia.

Moreover, the distribution of studies according to the year of publication in Fig. 3 shows that the time span of the studies was 1992–2022, and most studies were published in 2019.

In the reviewed studies, interventions on the use of health education and health promotion approaches, including community participation, media campaigns, training workshops, and educational sessions, have been investigated at both organizational and community levels. Educational sessions held as lectures, group discussions, and the use of educational booklets have been the most common interventions, occurring in 16 studies (Fig. 4).

As shown in5, interventions from 20 studies were examined at the organizational level, and 25 studies were examined at the community level. In addition, individual-level training, such as face-to-face training, were also held, which can be subsumed under the two

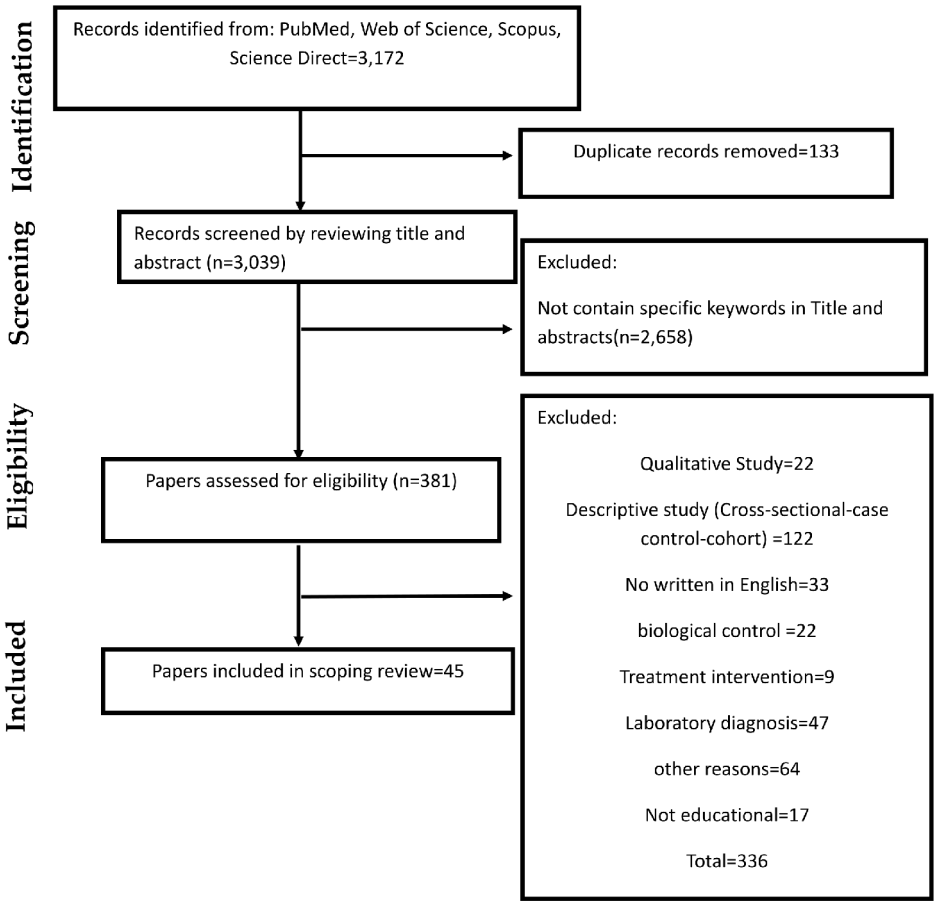

Fig. 1 Flow chart of literature search for education-based interventions for Aedes-borne disease control (1992–2022) according to the PRISMA-ScR

organizational and community levels, indicating that there is no need for a third level (individual level).

Education at organizational level

Overall, 20 selected studies had been conducted at the organizational level in different settings, such as schools, barracks, factories, and healthcare organizations. The types of educational interventions at this level were as follows: seven studies focused on educational interventions through holding educational sessions such as lectures, group discussions, and educational booklets; five studies involved campaigns; one study utilized workshops; one study used social media (Facebook, Instagram); and six studies included training classes using digital media.

Schools were found to be an appropriate place for providing education about diseases transmitted by Aedes mosquitoes, as discussed in this scoping review [33, 34, 39, 50–52, 59, 60, 65, 67, 68, 71–73]. In a school in Malaysia, a health education program was implemented to prevent dengue fever, in which students shared the messages and information they had obtained through reading an educational booklet with their family and friends. As a result, this educational program raised awareness of dengue fever and Aedes mosquito among students [34]. The effect of educational interventions to reduce Aedes mosquito infestation in schools was observed, resulting from the reduction of mosquito reproduction and improved water quality [65]. Educational interventions were implemented in a school in Argentina on dengue fever through lectures, reading educational booklets (including the symptoms and prevention methods of dengue fever) and teaching 10-year-old children to inform their parents. This simple act of encouraging children through training raised their awareness, and the students transferred the learned training effectively to their parents. This strategy is a potentially low-cost way of sharing information about dengue prevention [51]. School students in Colombia received educational interventions on identifying dengue symptoms, transmission routes, risk factors, and the perceived importance of solid waste as breeding places for mosquitoes.

Moreover, a weekly school cleaning campaign was implemented to identify and remove potential breeding places for vectors and collect solid waste around

Table 1 Characteristics of included studies on education-based interventions for Aedes-borne disease control (1992–2022)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
1	Charmagne G Beckett [40]	Indonesia	2004	Interventional	Factory workers	Organizational level	• Lecture on the signs and symptoms of dengue and ways to prevent the disease. • Posters in the health clinic. Handouts given to each volunteer with an explanation of symptoms.	Enhanced knowledge and awareness of dengue among the volunteers.
2	Scott Kitchener [56]	Australia	2002	Interventional	Soldiers	Organizational level	• Lecture on the signs and symptoms of dengue and ways to prevent the disease a) Providing written instructions on necessary actions in case of symptoms	Prevention of local transmission through early notification and prevention of transmission through isolation.
3	Carlos Alberto Ruggerio [69]	Argentina	2021	Interventional	Health office workers	Organizational level	• Two workshops planned to train 15 health office workers. • Theoretical and practical training was provided to assistants, including a complete class on mosquito life cycle and oviposition site identification. Implementation of a prevention campaign by municipal workers.	The results show that the mosquito is present in the territory and spreading. Prevention activities by municipalities are insufficient to generate an effective sanitary response, and there is a need to improve education programs for the population regarding the life cycle of the vector.
4	Gowda Giriyanna [47]	India	2015	Interventional	Workers	Organizational level	Lectured using demonstration charts in the local language, supported by audiovisual aids and discussion.	Improved Awareness regarding dengue fever and its prevention.
5	Francisco Fernandes Abel Mangueira [33]	Brazil	2019	Quasi-experimental	First-Year university students and police officers	Organizational level	• Comprising initial explanations, registration of the students on the distance-learning platform, and carrying out the intervention missions. Posting photographs using specific hashtags (#Zikamob) on social networks, such as Instagram or Facebook.	The students changed their attitudes and behavior regarding their engagement in actions for the prevention of arboviral diseases.

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
6	Rattanam AhbiRami [34]	Malaysia	2020	Interventional	Secondary school children	Organizational level	• Health education lesson, which started with a 15-minute lecture using the booklet. • Interactive sessions such as discussions, briefings, and question-and-answer were included. Students shared the messages and booklet they obtained through the study with family and friends.	The intervention improved students' knowledge related to dengue in schools. Age and dengue history were identified as the primary determinants influencing the high practice level in both areas.
7	Kristen Bartlett-Healy [39]	USA	2011	Campaign	Students	Organizational level	• Four separate educational events included a 5-day elementary school curriculum in the spring. Distribution of educational brochures.	There were reductions in container habitats in sites receiving education, but these were not significantly different from the control.
8	Maria Julia Hermida [51]	Argentina	2021	Interventional	Students	Organizational level	• Lecture on dengue fever. • Reading the booklet on dengue fever. Educating parents using an educational pamphlet.	There was an increase in students' awareness and an increase in parents' knowledge after they were taught by the students.
9	Carlos M. Hernández-Suárez [52]	Mexico	2016	Campaign	Personnel schools	Organizational level	Implement a special statewide campaign focusing on teaching janitors of elementary schools to locate and eliminate mosquito breeding places in schools.	Reduction in dengue incidence compared to the previous year.
10	Afonso Dinis Costa Passos [67]	Brazil	1998	Interventional	Students	Organizational level	Joint activities by public agencies: • Motivation and work by the population during routine home visits. • Production and use of educational materials. • Communication with the population by letter and cards. • Vector reporting by the population. • Use of mass media. Participation by schoolchildren.	The preventive campaign helped quell the disease in the city, leading to a drop in the number of susceptible individuals and observable changes in the behavior of the population towards potential breeding sites.

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
11	Lakmini Radhika [68]	Sri Lanka	2019	Cohort	Students (13–15 years old)	Organizational level	• Lectures using PowerPoint. • Video presentations. Group discussions.	There was an increase in the level of awareness among students after the intervention program.
12	Charuai Suwanbamrung [72]	Thailand	2012	Participatory action research	Children	Organizational level	• Training sessions. • Group discussions and consensus. • Promotional campaigns. Operational meetings.	There was an increase in the children's knowledge and activities, along with a decrease in larval indices ratio.
13	Hans Jorgen Overgaard [65]	Colombia	2016	Cluster randomized controlled trial	Rural primary school children	Organizational level	The dengue educational component included lessons on symptoms, transmission and risks, vector biology/ecology/control, and the role of solid waste as mosquito breeding sites.	The intervention reduced the Breteau Index, decreased mosquito breeding, and improved knowledge among school students after the educational program.
14	Newton G. Madeira [59]	Brazil	2002	Interventional	Students from the 5th and 6th elementary	Organizational level	• Didactic activities on the disease, causal agent, transmission, and prevention. A 23-minute film titled "Dengue, Join the Fight" was shown; after the film, a debate was organized, questions were raised, and an exercise book was distributed.	The didactic intervention was successful in developing knowledge, leading to increased awareness of the importance of preventative measures that should be taken against the vector and the disease.
15	Diana Sarmiento-Senior [70]	Colombia	2022	Interventional	Rural primary school children	Organizational level	• The educational intervention included lessons on identification of dengue symptoms, transmission routes, risk factors, the biology, ecology, and control of vectors, and the importance of solid waste as mosquito breeding sites. A weekly school clean-up campaign consisting of identifying and eliminating potential vector breeding sites and collecting solid waste around the school.	There were increases in knowledge scores among students, their teachers, and their parents regarding dengue disease. The attitude and practice scores of students receiving the interventions also increased.

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
16	Seif S. Al-Abri [35]	Oman	2020	Campaign	200 teams, each with 5 members under supervision	Community level	• Inspecting every single household. • Identifying breeding sites. • Performing health education to inform residents about controlling breeding sites. • Performing insecticide spraying if breeding sites were identified. A media campaign was launched simultaneously.	Rapid notification and early community-wide, extensive vector control activities effectively contained the autochthonous dengue virus outbreak.
17	Dewi, Ari Pristiana [43]	Indonesia	2019	Quasi-experimental	Household	Community level	• Training sessions for key stakeholders. Awareness campaigns for organizing communities.	The results showed a significant increase in changes in the level of attitudes and actions of families in the prevention of dengue fever by using audiovisual media.
18	Charito Aumentado [36]	Philippines	2015	Campaign	Health staff	Community level	• Several training sessions for key stakeholders. • Awareness campaigns for communities were organized. A series of advocacy activities were conducted by the Department of Health and partner organizations, including the distribution of information, communication, and education materials; broadcasting of radio messages; and featuring radio guest speakers, along with other health promotion activities.	The campaign was effective in reducing the prevalence of dengue fever, and awareness was heightened among foreign aid workers following a small cluster of dengue cases among them.
19	Norma Gorrochotegui-Escalante [48]	Mexico	1998	Interventional	Community members	Community level	Community participation was solicited through a simple training program on copepod rescue before drum cleaning.	Results showed good cooperation and a reduction in larvae: 37.5% for drums, 67.5% for flower vases, and 40.9% for tires.

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
20	Kristen Healy [49]	USA	2014	Interventional	AmeriCorps volunteers	Community level	Active community peer education was utilized in a source reduction program involving AmeriCorps volunteers. The volunteers received training on peridomestic mosquitoes and learned basic strategies to reduce the number of container habitats for mosquito larvae in backyards.	There was a significant reduction in container habitats in the sites where the volunteers actively engaged the community compared to untreated control areas in both counties.
21	Brian Kay [54]	Vietnam	2005	Interventional	Community members	Community level	• Health collaborators were each responsible for monthly inspection of about 100 houses. • Delivery of health education messages and reporting of any suspected dengue cases to the communal health center. • Clean-up campaigns. • Providing household support to the aged and infirm. Participation in dengue or project-oriented plays, songs, quiz nights, and in one district, a Meso football cup.	The intervention led to the eradication of Aedes aegypti in two communes, resulting in no dengue cases detected in any commune since 2002.
22	Kholedi, A.A.N [55]	Saudi Arabia	2012	Case–control study	Community members	Community level	• Door-to-door health education campaign. • The campaign addressed issues related to raising public awareness about the causes of dengue fever infection, measures of prevention, and the importance of early detection and management of suspected cases. It was implemented by trained volunteers and selected schoolteachers in Jeddah.	Face-to-face health education significantly decreased the risk of dengue infection.

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
23	Martine Noel [62]	New Caledonia	2005	Interventional	Community members	Community level	• All the agents hired took part in a three-day basic training session; "educator" agents had an additional two-day training session in communications. At each dwelling involved, the educator agents were asked to: carry out an initial intervention to educate the inhabitants, and make a control visit about one month later to the same dwelling.	The percentage of dwellings with potential breeding areas decreased significantly after the agents' visits, an impact that was maintained for at least three weeks afterwards.
24	Casey Parker [66]	Honduras	2019	Pilot study	Community leaders and stakeholders	Community level	• A two-week workshop on basic mosquito biology, ecology, and control was delivered at Universidad Nacional Autónoma de Honduras. The workshop attendees represented community leaders as well as other stakeholders including university faculty and students, doctors, nurses, engineers, and government officials. • Participants were trained on how to inspect residential and commercial properties for larval development sites and communicate with residents about these sites, their impact on human and animal health, and how to prevent those sites from producing mosquito larvae through source reduction. Workshop attendees were then able to apply this knowledge to home visits around their community.	The two-week workshop was successful in training a diverse group of community leaders and other stakeholders on various aspects of mosquito biology and control. Workshop attendees were able to immediately apply this knowledge to an underserved community in the city with high dengue incidence.

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
25	Manirat Therawiwat [75]	Thailand	2005	Community-based approach	Health volunteers, village headman, community schoolteachers, sub-district health officers, and Tambon (Sub-District) Administration Organization members	Community level	• Active participatory learning and action. • Small group discussions. Brainstorming and continuous dialogue were the main educational methods.	The program was quite successful. Knowledge, perception, self-efficacy, and larval survey practices in the experimental group were significantly higher than before the experiment and higher than in the comparison group. The Container Index, House Index, and Breteau Index decreased sharply to better than the national target. Community status as community leaders was the best predictor for larval survey behavior at the first survey. Participating in the study program activities was the best predictor at the end of the program.
26	Ashmin Hari Bhattarai [41]	Nepal	2019	Interventional	Household heads or spouses in the study groups	Community level	• Dengue prevention leaflets were delivered to each household by Female Community Health Volunteers during home visits. Dengue prevention leaflets were combined with SMS reminders via mobile phone.	The intervention was effective in increasing knowledge. Mobile SMS is an effective, acceptable, and appropriate health intervention to improve dengue prevention practices in communities. This intervention can be adopted as a promising tool for health education against dengue and other diseases.

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
27	Pattamaporn Kittayapong [57]	Thailand	2012	Education campaign	Community leaders, local administrative authorities, municipal mayors, and local public health Officers	Community level	• Training of active health volunteers by a public health expert. • Trained eco-health volunteers carried out outreach health education and vector control during household visits. Management of public spaces and public properties, especially solid waste management, was efficiently carried out by local municipalities.	An eco-friendly dengue vector control program was successfully implemented in urban and peri-urban settings in Thailand through intersectoral collaboration and practical action at the household level, resulting in a significant reduction in vector densities.
28	Roberto Barrera [38]	Puerto Rico	2019	Community-based approach	Community leaders	Community level	• Distributing educational handouts to adult residents. Hired personnel were instructed on the transmission of viruses by Aedes.	Mosquito density significantly changed, and mosquito pools were decreased.
29	Susanta Kumar Ghosh [46]	India	2011	Community-based intervention	Community members	Community level	• A health education campaign was performed using lectures and a live demonstration of larvivorous fish feeding on mosquito larvae. Live larvae collected from households were also shown to the villagers, and maintenance of the fish within small water-storing tanks was further explained. Interpersonal communication with each household was established during each monitoring survey.	The study successfully determined the comparative efficacy of artificially maintaining populations of two non-native fish to control mosquito vectors. Participants gained new knowledge from the information, education and communication campaigns. Indoor cement tanks were the most preferred Aedes aegypti breeding habitat and had a significant impact on Aedes breeding (Breteau Index) in all villages in the one-week period. In the one-month period, the impact was most sustained in Domatmari, followed by Srinivaspura and Balmanda. After fish introductions, chikungunya cases in Domatmari, Srinivaspura, and Balmanda were reduced.

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
30	Francisco Espinoza-Gómez [45]	Mexico	2002	Randomized community trial.	Householders	Community level	• The educational campaign consisted of a series of visits house by house. • The inhabitants, principally housewives, were offered a talk about the importance of dengue, ways to prevent it, and the biological characteristics of Aedes aegypti. • Such talks were reinforced with group meetings in which a dengue video was shown and a socio-drama was presented in the kindergarten of the area. • In each visit, the message was supported with a small gift, consisting of sweets, stickers, and calendars related to dengue and the Aedes mosquito.	The educational campaign reduced Aedes aegypti breeding places more effectively than the use of chemical spraying, and the combination of both treatments can reduce its efficiency, possibly because of the false expectancy of protection that spraying creates.
31	Andrea Caprara [22]	Brazil	2015	Cluster randomized trial	Community members, community leaders, professionals related to the municipal endemic diseases control program, and professionals working at the health centers	Community level	• Community workshops. • Community involvement in clean-up campaigns. • Covering elevated containers and in-house rubbish disposal without larviciding. • Mobilization of schoolchildren and senior inhabitants. Distribution of information, education, and communication materials in the community.	Embedding social participation and environmental management for improved dengue vector control was feasible and significantly reduced vector densities.

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
32	Clara Beatriz Ocampo [64]	Colombia	2009	Interventional	Community members	Community level	• Each house in the study neighborhoods was visited by two project members. • Residents were informed about the dengue problem and the biology of the vector. • Brochures were distributed in homes. The project team located mosquito-infested, water-holding containers present in the house, showed them to the residents, and explained the mosquito life cycle.	The interventions did not achieve significant differences in vector abundance among the treatments. However, the interventions achieved a significant reduction in entomological indices compared with those observed during the pre-intervention survey
33	Pierre Echaubard [44]	Colombia	2020	Case study	Community members	Community level	Implementation of a place-based educational campaign on dengue disease; vector biology; ecology and control; role of solid waste, clean water, and health relationships.	The project's interventions implemented so far have contributed to the emergence of culturally relevant social innovation products and provided initial clues regarding: (1) the conditions allowing social innovation to emerge, (2) specific mechanisms by which it happens, and (3) how external parties can facilitate social innovation emergence.

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
34	Yadlapalli Sriparvathi Kusuma [58]	India	2019	Interventional	Community members	Community level	• Existing health educational materials (pamphlets, posters, banners, audio message recordings) were collected from the municipal authorities by the research team and utilized in these clusters. • At least one health education session specifically on dengue in each cluster. Visits were utilized to educate people through informal chats and to inform and invite them to the health education session planned for the subsequent day.	The intervention resulted in a significant increase in knowledge regarding the cause, symptom perception, and mosquito behavior in terms of breeding and biting habits. The practice of personal protection measures increased significantly. The participation of people increased during the intervention compared to the routine program. Health education-based interventions are instrumental in improving people's knowledge and behavior.
35	Muhammad Shafique [71]	Cambodia	2019	Cluster randomized trial	Community members	Community level	• The local health education materials including pamphlets, posters and flip charts were prepared based on these sketches and messages which were disseminated to the communities through health volunteers, megaphone announcements and songs. The health volunteers were trained in communication and community mobilization skills to ensure effective message delivery and active community engagement in the project.	The community-led COMBI strategy resulted in high acceptance and perceived effectiveness of the interventions in target villages. Participants perceived that the interventions resulted in a reduction in Aedes mosquitoes and dengue cases. The presence of larvae in the water despite the use of PPF was a source of concern for some participants; however, this was overcome in some cases with proper health education through health volunteers. Interpersonal communication through health volunteers was the most favored method of transmitting prevention messages.

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
36	Wasantha P Jayawardene [53]	Sri Lanka	2011	Interventional	Community members	Community level	• Two advocacy programs were conducted to negotiate with and obtain support from multiple community stakeholders, including political, religious, community organizations, and business leaders, as well as high-level government officials. • The advocacy campaigns comprised speeches and demonstrations designed to generate understanding and support among targeted stakeholders. Two awareness programs were conducted for teachers and two for parents.	In intervention areas, all proportions of larval indexes were found to be significantly lower following the intervention. Surveillance data showed a reduction in case load for the urban area and a reduction in the rural area. If properly involved and guided, school children can be an asset to mosquito-borne disease control; the education sector could be an important partner in dengue fever and dengue hemorrhagic fever control.
37	Witaya Swaddiwudhipong [73]	Thailand	1992	Health education campaigns	Health care personnel, government officers, school children and teachers, and Community members	Community level	• Health education campaigns through house-to-house visits by trained health workers. Each health worker, accompanied by two school children, educated people about the health problems of the disease and the control measures for reduction of larval breeding sources in their premises.	Reduction of Aedes larvae in sources of larval habitats was due to various larval control measures. The introduction of larvivorous fish may be an effective method of larval control for these containers.

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
38	Francisco Nogareda[63]	Solomon Islands	2013	Interventional	Clinical staff, health care professionals, and community members	Community level	• Clinical training seminars based on WHO clinical management guidelines for doctors and nurses. • Implementation of diagnostic and case management protocols for health care professionals. • Vector control activities. Public communication campaigns including press statements, radio messages, and house-to-house delivery of dengue information pamphlets educating the public on the prevention of mosquito bites, the signs and symptoms of dengue, and promoting early health-seeking behavior.	Aedes aegypti and Aedes albopictus were identified in Honiara. Outbreak response measures included clinical training seminars, vector control activities, implementation of diagnostic and case management protocols, and a public communication campaign.
39	Gérard Ulíbarri [76]	Guatemala	2016	Interventional	Health workers	Organizational level	• Web-based training of local health personnel in vector control • Cluster-randomized assignment of ecological ovillantas or standard ovitraps to capture Aedes aegypti mosquito eggs Community engagement to promote participation of community members and health personnel in the understanding and maintenance of ovitraps for mosquito control	Improved knowledge of vector control. More eggs were trapped by ecological ovillantas than standard ovitraps over the 10 months.
40	Alejandra Taborda [74]	Colombia	2022	Interventional	Community members	Community level	• The regular control program consisted of insecticide spraying, inspection and control of potential breeding sites Community education	Intervention generated an additional cost of USD20.9 per household and an incremental effectiveness of 0.00173 (reduction in the probability of reported dengue cases)

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
41	Amy C. Morrison [61]	Peru-Cambodia	2021	Interventional	Community health workers, household residents	Community level	• Teaching using detailed systematic instructions with pictures or drawings for users with low literacy Using a video tutorial on how to use test kits	Findings support the need for further implementation research on the appropriate level of instructions or training needed for diverse devices in different settings, as well as how to best integrate RDTs into existing local public health and disease surveillance programs at a large scale.
42	José Alejandro Martínez-Ibarra [60]	Mexico	2012	Interventional	Children four to six years old	Organizational level	• A 10-min educational video starring a cartoon character called Jo Jo Mosquito The Touch Table Technique, known as the Touch Table Fair drawing contest as a reinforcement technique	The results of the study showed that combining both techniques to teach children about mosquito control is a potentially useful tool for control efforts in Mexico and elsewhere in Latin America.
43	Agus Hendra [50]	Indonesia	2022	Interventional	Students	Organizational level	• Training for peer educators Focus group discussion	Health promotion with peer education is an effective technique for adolescents to increase knowledge and change behavior. Dengue hemorrhagic fever is a community disease; therefore, modification of the environment is necessary with cooperation from all sectors. The health unit in schools must use varied methods to deliver information to youth and involve peers as mentors.

Table 1 (continued)

	First author	Country	Published year	Type of study	Participants	Level of intervention	Intervention	Outcomes
44	T G D Chandlmaleet [42]	Colombo	2017	Interventional	General practitioners	Organizational level	• A seminar was conducted on management of fever without a focus and dengue fever for all who took part in the study. The seminar included 3 lectures and small group discussions A pre-recorded video compact disc (VCD) with lectures copy of national guidelines on management of dengue fever and information	This study showed that a significant improvement in knowledge could be made by updating knowledge of GPs through educational programmes to improve standards of care.
45	Anu Balkrishnan [37]	India	2019	Interventional	Physician	Organizational level	• Programs aimed to create awareness and inoculate the guidelines among the residents through four training sessions. Two open forums on the same were also conducted for all staff involved in the management to further increase the efficiency of management.	The study affirms that compliance with WHO guidelines on dengue management in India can be further improved by regular physician training on the guidelines. Simultaneously, this educational intervention not only improves patient outcomes but also directs proper resource utilization, especially regarding platelet transfusion and antibiotic use.

the school. This campaign successfully raised awareness among students, teachers, and their parents about dengue fever [70]. A study in Mexico educated four- to six-year-old children about dengue prevention and mosquito behavior through two main strategies: a 10-minute educational video featuring a cartoon character called Jo Jo Mosquito and the Touch Table Technique, which included a drawing contest as a reinforcement technique. Two months after the teaching session, the houses were visited to determine the impact of the interventions on children's behavior and family mosquito control [60]. A peer education program was conducted in a high school in Indonesia to prevent and manage dengue fever. The program involved training peer educators for four days using Google Meet and WhatsApp. The training covered different aspects of dengue, including general information, etiology, clinical manifestations, transmission, prevention, and management. The peer educators delivered this information to students through presentations, videos, and discussions. The study validated the effectiveness of this peer education intervention in increasing knowledge and changing the behavior of adolescents about dengue fever [50].

In addition to schools, educational interventions on dengue fever among soldiers, health staff, and house workers also led to interesting findings [40, 47, 56, 69]. Soldiers returning to North Queensland, Australia, received oral information about the signs and symptoms of dengue fever, along with written instructions on what to do if these symptoms occur, including early reporting to medical facilities. Two weeks before the soldiers' return, their living areas were placed under strict vector control measures to reduce the risk of dengue fever. Dengue should be reported immediately to the state public health authorities and quarantined until a definitive diagnosis is made. These interventions have successfully prevented local transmission in these circumstances through early notification of cases and prevention of transmission

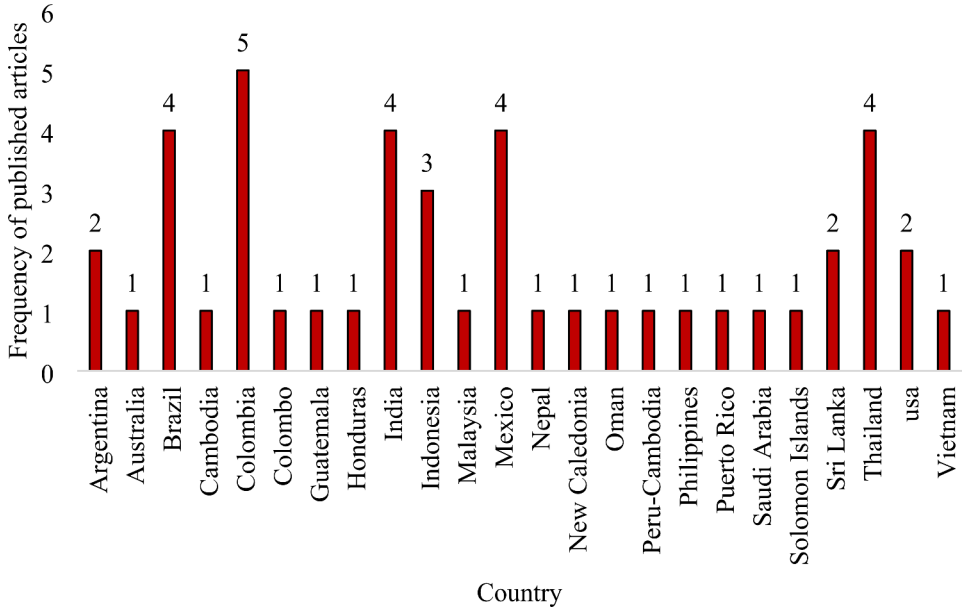

Fig. 2 Distribution of education-based interventions for Aedes-borne disease control by country (1992–2022)

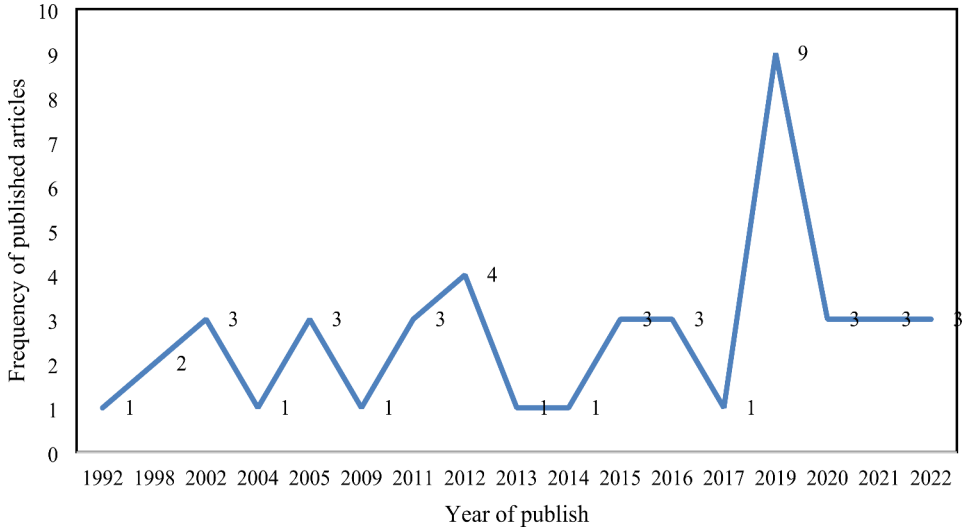

Fig. 3 Distribution of education-based interventions for Aedes-borne disease control by year (1992–2022)

via the isolation and cooperation of the ADF and state and local public health authorities in vector control [56]. In an Indonesian factory, interventions were implemented on the Aedes mosquito. Trained doctors gave lectures on the signs and symptoms of dengue fever, transmission of dengue virus and ways to prevent it to the factory workers. Educational posters were also put up in the health clinic of the factory. Additionally, an educational booklet explaining the signs and symptoms of dengue fever was given to the workers. These interventions led to an increase in workers' knowledge and awareness of dengue fever [40]. In another study in India, an educational intervention was provided to employees working in urban health centers in Bangalore city. The educational intervention on dengue fever was provided in three groups as a lecture using demonstration diagrams in the local language and audio-visual aids. During the training sessions, mosquito larvae were shown to all employees individually, and an entomologist provided necessary explanations about examining the larvae. Awareness of dengue fever and its prevention was low among employees before the study, but it improved significantly after the training sessions [47].

Education at the community level

A total of 25 studies were community-based as all the community members were included in the educational intervention. The types of educational interventions

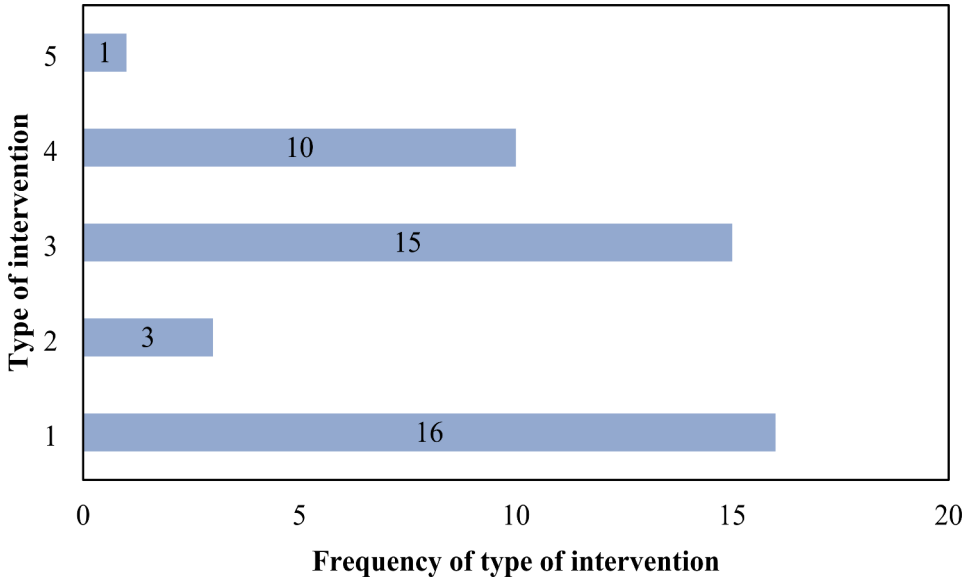

Fig. 4 Distribution of education-based interventions for Aedes-borne disease control by type of intervention (1992–2022). 1 = Educational sessions, such as lectures, group discussions, and educational booklets; 2 = Workshops; 3 = Campaigns; 4 = Educational classes using digital media; 5 = Social media platforms (e.g., Facebook, Instagram)

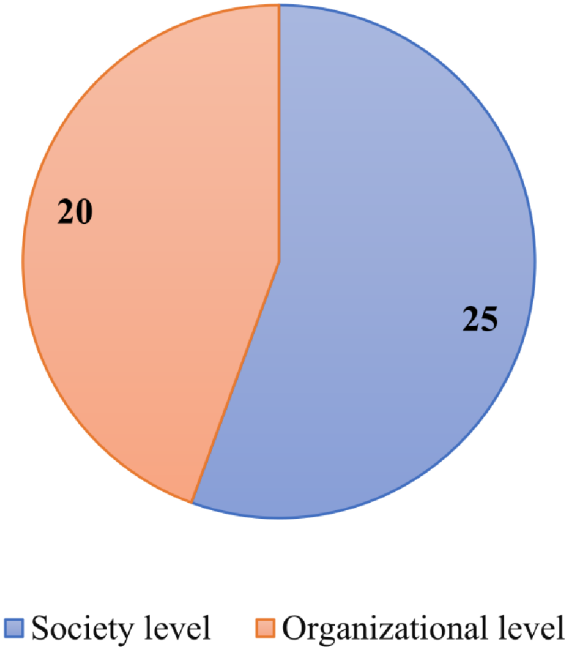

Fig. 5 Distribution of education-based interventions for Aedes-borne disease control by level of intervention (1992–2022)

carried out at this level were as follows: nine studies focused on educational sessions such as lectures, group discussions, and educational booklets; ten studies involved campaigns; two studies utilized workshops; and four studies included educational classes using digital media.

An educational campaign was held in Oman to reduce dengue fever. This campaign was conducted by 200 teams whose tasks included inspecting each household, identifying breeding sites, providing health education to inform residents about controlling breeding sites and carrying out insecticide spraying if breeding sites were identified. Rapid notification and basic vector control activities at the community level effectively curbed the spread of the dengue virus [35]. An educational intervention was conducted in Indonesia using audio-visual media to improve family behavior in preventing dengue fever. This study showed that changes in the attitude and performance of families in preventing dengue fever using audiovisual media, resulted in a significant increase [43]. Community-based peer education on Aedes mosquito reduction was conducted in New Jersey using AmeriCorps volunteers (a national organization in the United States that provides disaster, economic, environmental, health, and education services). It was provided by peers and included (1) active instructions (home visits and educational content provided to household members), (2) social educational events, (3) tire collection days, (4) trash digging days (the residents were asked to place their trash cans on the curb so that volunteers could dig drainage holes in the bottom), and (5) media content. It showed a significant reduction of container habitats in places where volunteers actively engaged the community compared to uncontrolled areas. Therefore, active education based on active community peers can be an effective means of reducing the sources and a vital means at home to resist household mosquitoes [49].

A door-to-door health education campaign was held after a sharp rise in dengue cases in Saudi Arabia. This campaign was developed and put into practice by Preventive Health Affairs, Jeddah Municipality, Department of Education for Boys and Girls, Department of Religious Affairs and Information Department in Jeddah Province, together with King Abdulaziz University. Dengue preventive measures and the importance of early diagnosis and management of suspected cases were taken by trained volunteers and teachers from selected schools in Jeddah. It was a door-to-door campaign in areas with a high dengue prevalence based on surveillance data. Face-to-face health education significantly reduced the risk of dengue fever [55]. A study in two villages in Thailand implemented a community empowerment program on dengue fever. In this program, key stakeholders at community including village health volunteers, village head, school teachers, district health officers and administrative organization members were included. The main strategies within this program were continuous educational activities developed on the basic concepts of a problem-solving process, including problem identification, problem clarification, identification of possible solutions, project development, implementation, and evaluation. Active collaborative learning and action, small group discussions, brainstorming, and continuous dialogue were the primary educational methods. Each of the key community stakeholders then planned dengue control activities with family members in their area. At the end of the empowering program, awareness, perception, self-efficacy, and ways of checking larvae in the village residents increased significantly [75]. In another study, an education program at the community level was run through SMS and face-to-face education at home in Nepal. The interventions included: (a) dengue fever prevention brochures delivered to each family during home visits, (b) fever prevention brochures with SMS reminders via mobile phone. SMS reminders included (1) dengue fever prevention reminders, (2) searching for and eliminating mosquito breeding sites, such as water storage, garbage disposal, and solid waste storage in and around homes, and (3) preventing exposure to Aedes mosquito bites. Examples are using long-sleeved clothes, insect repellents, bed nets, and screening windows and doors sent twice a week via cell phone text messages. This educational program, which combined mobile phone text messages with conventional methods such as dengue fever prevention brochures, could create a better change in people's knowledge and performance than conventional methods alone. Mobile SMS is an effective, acceptable, and suitable health intervention to improve dengue prevention practices in communities. This intervention can be a promising means of health education against dengue fever and other diseases [41] .

A dengue prevention education campaign was held in Colima, Mexico. The campaign included door-to-door visits by students. In visits to the residents, who were mainly housewives, explanations were provided about the importance of dengue fever, ways to prevent it, and the biological characteristics of Aedes aegypti. A group meeting was held in which a video was played on dengue fever. A sociodrama was presented in a district kindergarten. In addition, a small gift consisting of sweets, stickers, and calendars related to dengue fever and Aedes mosquitoes was delivered during each home visit. Community leaders facilitated the entrance into the houses, and thus, an average of three visits were made to each house. At the end of the training campaign, Aedes aegypti breeding sites were effectively reduced [45]. A health education intervention was implemented in an impoverished area of India with the Delhi Municipality and NGOs. The educational materials included pamphlets, posters, banners, and audio messages that were collected and used by the municipality. A plan to carry out interventions on dengue fever and its prevention was made in consultation with the intervention partners, including the municipality, non-governmental organizations and the employer of the immigrants, a construction company. Before each training session, the houses were visited, and in addition to training the family members, they were informed about the time of the group training session. A total of 15 health education sessions were held specifically on dengue fever. The intervention led to a significant increase in knowledge about the causes and understanding of mosquito symptoms and behavior in terms of breeding and biting habits, as well as increased personal protection measures and active participation of community members [58] .

Discussion

This scoping review provides evidence for educational interventions to control the Aedes mosquito and the diseases transmitted from 1992 to 2022. Most data were derived from studies from Latin America and Asia. The present study showed that the health education intervention was effective in preventing and controlling the Aedes mosquito and the diseases transmitted. The interventions were grouped into two categories of educational interventions at the community and organizational level, and the individual level was also included in this group.

The present study showed that community-based health education had valuable results for the prevention and control of Aedes mosquitoes. These trainings were provided through campaigns, virtual training, workshops and training sessions and distribution of training packages. Most of these interventions were carried out by visiting individual residential houses in the study area and educating the residents. In this regard, researchers stated that among chemical, biological, and community-based

interventions, integrated interventions, including community participation and community mobilization, are the most effective [26, 77]. Bowman and Alvarado-Castro [26, 78] contended that involving the community with the aim of mobilizing it to adopt preventive behaviors requires influencing personal, interpersonal, and environmental factors. Community participation is sustainable if it includes the local evaluation of evidence and co-development of interventions that best fit local circumstances and culture [26]. Therefore, educational and awareness-raising programs managed by relevant organizations, as well as top-down directive approaches, are a weak foundation for achieving community commitment and ownership of interventions.

Studies that implemented interventions to prevent and control Aedes mosquitoes at different organizational levels, such as schools, barracks, factories, and healthcare organizations reported effective findings. This finding shows that significant improvements have been made in strategies to deal with Aedes mosquito and training has followed from the home environment to organizational settings. A very common organization was schools. The results showed that schools are effective educational environments for health education regarding the Aedes mosquito and diseases transmitted. Schools are an important place for community members to gather, including students, students' families, and school staff. Students can act as a basic link between educational interventions and the community, so they transfer the education they have learned to their families. Investing in the young generation of students at the age of learning is also one reason for the success of school education. This issue also becomes important as schools are the typical habitats for vector mosquitoes, including Aedes [79]. Besides raising awareness, health education interventions managed to reduce the infection rate of immature forms of Aedes mosquitoes in schools. In line with our study, Díaz-González contended in a review that the use of ludic strategies and the direct participation of children in mosquito control within families are among the most attractive and effective strategies for teaching dengue fever to children and adolescents. However, the persistence of protective behaviors has been poorly evaluated [80]. A study in Colombia stated that education through games and teaching families by children about how to control dengue fever improved knowledge and practice of dengue prevention, and most children fulfilled their commitment to educating their families [81]. Using educational interventions for students, school team and parents, as an important part of community, is an effective way to raise awareness of the Aedes mosquito and the diseases it transmits. It can contribute to the effectiveness of control programs against Aedes mosquito.

Training also proved effective in other organizations. Aedes mosquitoes are bred in different places such as villages, schools, temples, hospitals, hotels and factories [82]. For example, unattended solid waste from artificial and natural sources is the most significant potential risk factor for arbovirus vectors Aedes in hotels [83]. Employees and workers who work in such environments can be at risk of occupational transmission of vector mosquitos. Especially outdoor workers, such as construction workers and farmers who work in open areas for many hours of the day and night due to their job status, are often more exposed to vector mosquitoes [84, 85]. Therefore, it is essential to remove aquatic habitats from areas with large numbers of outdoor workers, such as agricultural fields, construction sites, outdoor sports, and outdoor recreation areas, and teach and protect people in such environments. Also, involving the people working in these environments in educational programs for this mosquito can be a positive step to effectively eliminate these habitats and cover part of the costs of the multifaceted programs to fight the Aedes mosquito. Like outdoor workers, because they spend long hours of the day and night in open and public environments, soldiers are among the groups at risk of diseases caused by mosquitoes. In the Caribbean region, it is believed that the casualties of British and French soldiers are high, which is induced by yellow fever and malaria [86]. It seems necessary to implement educational and control programs for Aedes mosquitoes in such settings.

Another organization to implement educational interventions is the healthcare organization. In this regard, Mulderij reckons that health staff must be trained and able to identify the most productive breeding places for Aedes mosquitoes. This training can help adopt standard operating procedures for entomological surveillance. Also, the health staff should evaluate the effects of the Aedes control program because these evaluations facilitate the implementation of program in the long run and can lead to more sustainability [27]. Interventions for the health staff at the forefront of control and prevention interventions [87] can include awareness-raising of the control methods, personal protective measures, and community participation. Community members are more responsive to health officials in health-oriented interventions, and interventions involving health staff in the community have already proven effective for malaria control, health education, breastfeeding promotion, infant care, and mothers' psycho-social well-being [19, 88].

Our assessment by the Cochrane Collaboration Risk of Bias Tool revealed that 46.7% of studies were with low risk of bias [22, 34, 37–39, 41, 45–47, 50, 51, 53, 57, 58, 60, 64, 65, 68, 70, 71, 76], while 53.3% were with high risk of bias [33, 35, 36, 40, 42–44, 48, 49, 52, 54–56, 59, 61–63,

66, 67, 69, 72–75]. This distribution demonstrates the variety of quality methods among the included studies. In line with these results, two systematic studies found that there were 50% and 62.5% high chances of bias [30, 89]. More than 90% of the studies described participant characteristics [22, 33, 34, 36–39, 41–47, 49–62, 64–76], which improved our understanding of the study participants, including students, soldiers, and community members. Furthermore, 49% of the studies [33, 34, 40–43, 45–47, 50–53, 57–60, 65, 66, 68, 70, 75] reported participant retention rates ≤ 70%, showing that these studies had acceptable participation levels. Nearly all studies (98%) detailed interventions [22, 33–42, 44–76]. By describing these interventions, we can understand how interventions were carried out and provide researchers with insights for future research. Studies reporting random sequence generation to reduce selection bias were found in 38% of the articles [22, 38, 39, 44–47, 51, 57, 58, 60, 61, 64, 65, 70, 71, 76]. 75% used valid outcome measurement tools, such as valid and reliable questionnaires [22, 33–35, 37–43, 45, 47–51, 53–55, 57, 58, 60, 63–65, 68–70, 72–76]. Applying valid outcome measurement instruments such as questionnaires is important during research since it ensures that the data collected accurately represents respondents' experiences and intervention effectiveness. Especially in Aedes-borne diseases, awareness of the community and change in its behavior directly contribute to disease control.

Public health implications

National vector control programs focused on insecticide spraying incur the cost of centralized planning, logistical structures, and large numbers of local personnel. These programs can benefit from community-based approaches and active technology to be more effective and cost-effective. Digital and mobile health technologies can help expand the reach and participation of programs, especially in hard-to-reach communities. Using social media, text messaging, and mobile apps to deliver educational messages and promote behavior change about mosquito control can be more scalable and interactive than traditional mass media campaigns. Researchers are suggested to understand the digital literacy, access, and preferences of the target communities.

It is useful to ensure sustainable financing, technical support, and community participation, as well as a multi-stakeholder approach, including the government, private sector, and community organizations. The ability of local health workers and community members to effectively use innovative tools and approaches, such as satellite images and artificial intelligence can be improved. Community mobilization by directing different actors to strengthen the resources and social network in society can expand the scope of intervention at the individual, group and regional level. In this sense, educational settings and employees from different settings such as workers, soldiers, and community leaders, are critical to the success of these interventions. A combination of different methods is suggested to fight mosquitoes and strengthen surveillance of suspected arboviruses. Interventions to improve environment are also suggested along with education at different community levels. In educational interventions, more attention should be paid to the participation of vulnerable populations who are less actively involved in the community, including the elderly or housewives. Additionally, support for these interventions should be provided at all levels.

Limitations

One limitation of this study is that the databases are limited to PubMed, Scopus, ScienceDirect, and Web of Science. While these databases are widely used in the medical and scientific community, they may not capture all relevant studies, particularly those published in regional or non-English journals. To address this limitation in future research, it is recommended to continue the search to include a wider range of databases such as Embase and local databases. The strength of this study lies in its methodology, as every step in data search, screening, experimental extraction, and cross-checking was taken to reduce the possibility of bias.

Conclusion

The present scoping review evaluates the effectiveness of educational interventions at various community levels for controlling Aedes-borne diseases, emphasizing the need for multidisciplinary collaboration. As the analyzed data showed, Aedes mosquito control focused on community participation seems to be the most effective approach to reducing infectious diseases. The development of education at different community levels, such as educational and occupational environments, can play a role in the effectiveness of societal education and may be more cost-effective. Maintaining the effect of this approach is challenging because it requires multi-sector and multi-disciplinary team participation and active community engagement over the long term. Therefore, future research needs to remove barriers to program implementation and maintenance. We recommend future research to address the issue of education according to regional and demographic characteristics of populations to provide more practical advice to countries struggling with Aedes control. We encourage countries with more advanced techniques and qualified labor to support countries with less advanced health systems in implementing effective, evidence-based educational interventions as part of integrated vector management strategies. Compatibility of interventions with different

cultural and economic environments improves global communication.

Supplementary Information

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Supplementary Material 1

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Author contributions
NSH and FP ZH conducted the search, screening and selection of articles, data extraction, drafting and revision of manuscript. AH and EA assisted with the search, screening and selection of articles. AH and ZH critically reviewed the manuscript and contributed to the drafting and editing of this manuscript. All authors read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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