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A systematic review of pre-service training on vaccination and immunization

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Abstract

Introduction: The World Health Organization's *Global Strategy on Human Resources for Health: Workforce 2030* sets policy recommendations and targets for in-service and pre-service training programs to improve workforce competency. To date, comprehensive reviews on immunization training have mainly focused on in-service trainings. This systematic review aimed to synthesize current literature on pre-service immunization training, including primary immunization competencies covered, methods used, outcomes on improving competencies and behavior change for immunization service delivery, and student readiness for immunization practice, in both low-resource and high-income settings.

Methods: A systematic search of seven scholarly databases identified published literature on pre-service training on immunization published between January 2001 and November 2021. It included all geographic regions and languages, study designs, and individuals preparing to enter the immunization workforce. Additional search methods included reviewing references of retrieved articles, scanning journals, and engaging pre-service training experts for unpublished reports.

Results: Search results yielded 5,611 articles; 39 articles met the inclusion criteria. Five articles were identified through other search methods. Studies took place mostly in high-income countries (35/44), targeted professional (medical, nursing, and pharmacy) students and tutors at health training institutions. Eight of the ten recommended immunization competencies were included in the curricula and methods used to deliver pre-service training varied. Teaching techniques and applied learning strategies using realistic situations increased students' knowledge, attitudes, and awareness of vaccine benefits; built confidence to administer vaccines and communicate with hesitant patients; and increased the likelihood of recommending vaccines.

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Declaration of Competing Interest

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

Disclaimer.

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Conclusion: This review was the first step to understanding pre-service training on immunization. Further research is needed to inform pre-service training programs in low- and middle-income countries, particularly for nurses, vaccinators with low-level educational backgrounds, and other healthcare professional students. Prioritizing essential audiences, designing and delivering practical training, and evaluating results will help prepare students for the immunization challenges of tomorrow.

Keywords

Pre-service training; Immunization; Vaccination; Workforce; Competency; Global health

1. Introduction

The World Health Organization (WHO) describes the health workforce as one of the six building blocks for health systems strengthening [1]. Workforce retention and development are also included as an indicator (3c) of the United Nations' Sustainable Development Goals: to increase "recruitment, development, training, and retention of the health workforce" [2]. The World Health Organization's *Global Strategy on Human Resources for Health: Workforce 2030* sets specific policy recommendations and targets to improve workforce competency for in-service and pre-service training/education programs, including accreditation and student graduation rates [3]. Moreover, the Immunization Agenda 2030 (IA 2030) strategic priority 2 recommends immunization topics in educational curricula for the health workforce [4]. *Expanded Programme on Immunization Prototype Curriculum for nursing/midwifery schools in the WHO African Region* sets standard competencies for nursing and midwife graduates and included objectives and priority topics that nursing and midwifery schools in the Africa region should cover, as well as suggested time allocation for each topic and teaching delivery format (e.g., classroom sessions, practical sessions, and/or during field placement) [5]. Having a competent workforce for immunization services is a critical determinant of vaccine acceptance, vaccine uptake, and completion of recommended vaccinations across the life course [6].

The *Standard Competencies Framework for Immunization Workforce* outlines 10 competency domains (2 foundational and 8 technical) that workers should acquire at each level of the health system (national, provincial, district/sub-district, community) to efficiently operate an immunization program [6]. The two foundational domains are 1) leadership and management (i.e., provide vision and direct resources for program support and implementation) and 2) vaccine preventable diseases and program. The technical domains include 1) advocacy and communications; 2) disease surveillance, investigation, and response; 3) human resources and performance management; 4) safety of vaccines and immunization; 5) monitoring, evaluation, and data use; 6) policy, planning, and finance; 7) vaccines, supplies, and logistics, and 8) vaccination service delivery. In the immunization workforce framework, expected worker competencies for each domain are defined by the health system level and the work functions at that level.

We conceptualized a framework, depicted in Fig. 1, to illustrate the stages of capacity-building interventions for immunization workforce development and the factors that

enable the achievement of desired outcomes during each stage. This framework is based on collective knowledge and expertise of the authors on learning and performance improvement, levels of workforce development described by Roche [7] and the employee lifecycle described by Cattermole [8].

As shown in Fig. 1, pre-service training is the first stage to build a qualified immunization workforce through a comprehensive curriculum on recommended immunization competencies, delivered by skilled teachers, and reinforced by field practice opportunities. After recruitment and during onboarding, new hire orientation (stage two) is critical to provide on-the-job support for the new hires and orient them to immunization delivery and local practices. The third stage of capacity-building continues throughout a worker's career when performance is supported through clear job descriptions for healthcare workers, continuing education or timely refresher training, and adequate resources, including guidelines and tools to enable workers to perform their job requirements. These three capacity-building stages, coupled with mentorship and leadership development across the lifecycle of the workforce, are important influencers of worker performance [9].

The primary outcomes of these stages of capacity-building interventions for immunization workforce development are qualified pools of applicants, positive changes in the knowledge, attitudes, and skills of current and prospective immunization health workers, increased confidence in recommending and administering vaccinations, and improved appreciation of the importance of vaccination. A qualified pool of applicants with these characteristics would support the targets to improve workforce competency set by The *Global Strategy on Human Resources for Health: Workforce 2030*, yet it is not clear in the literature how future healthcare workers are trained for their expected immunization responsibilities.

Health workers are primary influencers and sources of information on vaccination for parents and caregivers [10]. Inadequate or poor preparation of the workforce for immunization services delivery could put at risk the achievement and maintenance of immunization targets. However, comprehensive reviews of immunization training have often focused on curriculum review, implementation, and evaluation of in-service trainings [11,12]. The authors are not aware of any comprehensive or systematic review of pre-service immunization training of health workers.

Accordingly, we conducted a systematic review to synthesize the current literature on pre-service education and training on immunization in various geographical settings, by examining immunization competencies, training methods, outcomes, and reported student readiness, to serve as a first step to inform lessons learned and future pre-service training strategies on immunization. The findings of this review should help guide the academic institutions and ministries of health as they plan training interventions for workforce development, especially the global immunization community which encompasses low-, lower-middle, upper-middle, and high-income countries as classified by the World Bank [13].

2. Methods

2.1. Operational definitions

For this review, the authors define pre-service training as *health programs or interventions that generally award certificates or degrees that include preparing individuals to provide immunization services*.

The authors categorized pre-service training interventions into two types: a) immunization curriculum and b) short supplemental training.

- a. *Immunization curriculum* was defined as a comprehensive training program, often embedded in health professional training programs, covering multiple immunization-related competencies, and often using a mix of training methods throughout the program such as lectures and practical assignments.
- b. *Short supplemental training* was defined as shortened trainings that often supplemented the immunization curriculum to fill gaps identified in standard immunization curricula and/or were innovative ways to teach parts of the curriculum. These supplemental trainings covered fewer competencies than the immunization curricula, sometimes only focusing on one or two competencies in total.

2.2. Inclusion criteria

Articles in any language, published from January 2001 to November 2021 in peer-review journals and grey literature were considered for inclusion, regardless of the study design. The inclusion criteria for the articles included in this review were structured based on a specific Population, Intervention, Comparator, and Outcome (PICO) framework to help define the scope of the review (Table 1) [14].

The following types of articles were excluded: opinion papers, studies that focused on in-service training, and interventions not focused on immunization.

2.3. Literature search strategy

A librarian with expertise in systematic literature reviews searched in seven scholarly databases, including Medline (Ovid), Embase (Ovid), Global Health (Ovid), PsycINFO (Ovid), CINAHL (Ebsco), African Wide Information, and Cochrane. The keyword search strategy included *preservice, OR education, OR training, OR student, OR curricula/ curriculum, OR medical education, OR workforce development, OR capacity development, OR capacity building, OR workforce performance AND routine immunization* OR vaccine-preventable disease* OR immunization program* OR mass vaccination* OR vaccination coverage * OR vaccinator*. After removing duplicates and excluding articles based on title and abstract screening, full-text articles that met the pre-service training definition and inclusion criteria were reviewed independently by the first two of the authors. For any disagreement during the review process, the first two authors discussed until a consensus reached. The authors then conducted a secondary search which included the review of article references, journals (e. g., Human Resources for Health) for articles on this topic published

from 2001 to 2021, internet searches, and review of websites that publish any materials on pre-service education (e.g., Network for Education and Support in Immunization), and emailed experts with expertise in pre-service education requesting any additional unpublished reports.

2.4. Data extraction and analysis

The authors developed a Microsoft Excel template to extract consistent information about each study of the 44 articles included in the review, such as the purpose of study, population, study location, type of intervention(s), assessment/evaluation method, topics/competencies covered in the educational intervention(s), and key findings. Abstraction was done by two of the authors independently, and 100% inter-rater agreement was achieved after discussion and comparison of the information extracted and any disagreement in rating. The information was then synthesized by the authors' five main outcomes of interest as outlined in PICO.

3. Results

3.1. Article search findings

Fig. 2 presents the search flow diagram. The authors identified 5,611 articles through the initial database search. After removing 1,143 duplicate articles, another 4,358 of the remaining 4,468 articles were excluded due to having no relation to the topic. Abstracts of the remaining 110 articles were reviewed and 50 of these were eligible for full-text review based on the inclusionary criteria. After a thorough full-text review of each of the 50 remaining articles, 39 articles met the inclusion criteria. Secondary search methods yielded five additional articles, and a total of 44 articles were included in the systematic review. Of the 44 articles included, 42 were peer-reviewed articles and 2 were grey literature.

3.2. Overview of the studies reviewed – Characteristics of included studies, article type, and primary topics covered

3.2.1. Characteristics of included studies—Table 2 summarizes the 44 reviewed studies stratified by World Bank income categories. The majority ($n = 35$) were in high-income countries, with just three focused on low-income countries (Kenya, Malawi, and Tanzania) and five in lower-middle income countries (India, Indonesia, Nigeria, and Thailand). The studies, covering five continents and 21 countries, targeted the following populations: medical students/residents [21], nursing students [2], pharmacy students [14], mixed populations [3], and Expanded Programme on Immunization (EPI) tutors and health training institutions [4]. Search results did not identify any studies or interventions related to pre-service training for non-professional students (e.g., vaccinators, logisticians).

Our findings outlined below were analyzed based on three areas of interest from each reviewed article: the target population, competencies taught, and training methods used.

3.2.2. Immunization competencies identified in the literature on pre-service training—Thirty of the 44 reviewed studies reported on the competencies covered during pre-service training. Among those 30 studies, the two most commonly covered competencies were training on counseling and communication on immunization (67%)

and knowledge of immunization (60%). Of the 30 studies that reported on immunization competencies covered, 15 were focused on pre-service training for medical students, 2 for nursing students, and 13 for pharmacy students. When reviewing the competencies covered disaggregated by student type, there was some variation in the frequency of competencies reported, with vaccine administration having a notable difference across student groups. Vaccine administration was covered in pharmacy education in 12 of the 13 studies (92%), while it was only reported in 3 of the 15 (20%) studies for medical student training and none for nursing students. Communication and counseling, managing adverse reactions, knowledge of VPDs and immunization were the focus for nursing students training. Comparing reported pre-service training competencies to the recommended standard immunization competencies at the community level for the immunization workforce [6], 8 of the 10 competency domains (Management and leadership; Policy, planning, and finance; Vaccine service delivery; Vaccines, supplies, and logistics; Monitoring, evaluation, and data use; Safety of vaccines and immunization; Vaccine-preventable diseases (VPD) and program; Advocacy and communications) were included to some degree in the curricula as outlined in Table 3. Two technical competencies domains—Human resources and performance management; and disease surveillance, investigation, and response—were not reported. Fig. 3 presents the results of the immunization competencies reported in medical, nursing, and pharmacy pre-service training.

3.3. Reported training methods used for pre-service training interventions on immunization and their reported outcomes on immunization competencies and behavior change

Table 4 presents a summary of the training type (i.e., short training vs immunization curriculum), training methods, and reported outcomes in the 44 reviewed articles. Table 5 provides details on the characteristics of short, targeted training methods described in 23 of the 44 studies reviewed in terms of the population included and assessed, study settings, competencies measured, assessment method, and main findings related to an increase in measured competencies and self-rated competencies. Table 6 covers 21 of the 44 studies reviewed that described immunization curricula, highlights the measured and self-reported changes in students' competencies and behavior regarding immunization after the completion of their institution's immunization curriculum, as well as their perception of readiness or feeling prepared to enter the immunization workforce.

3.4. Immunization curriculum versus short supplemental training

3.4.1. Immunization curriculum—Twenty-one articles (i.e., 3 of 3 low-income, 1 of 5 lower middle-income, and 17 of 35 high-income country articles) reported on various curricula. In the reviewed papers, pharmacy curricula included the American Pharmacists Association's (APhA) Pharmacy-Based Immunization Certificate Program (15–19), a comprehensive immunization course with in-person lecture and skills laboratory option [20–23], and online instruction and skills laboratory [24,25]. For medical student curricula, studies reviewed included the United States Medical School Education and Residency training program with a component on immunization for medical students and residents [21,26–30] and the European version of their training program [31,32]. All four articles from low-income and lower-middle-income countries targeted EPI pre-service training institutions

and EPI tutors [33–36], and two of them used the WHO EPI Prototype Curriculum for Medical Schools and Nursing/Midwifery Schools in the WHO African Region [33,35].

Survey questionnaires were used to measure self-reported changes in competencies and behaviors. Evaluation of the outcomes of the American Pharmacists Association's (APhA) Pharmacy-Based Immunization Certificate Program revealed that pharmacy students thought they were well trained in immunization, vaccine administration, and response to adverse events following immunization (AEFI) [15–19]. Evaluation or assessment of other curricula post-training tended to focus on students' perception of adequate training received and time allocation for teaching vaccines, VPDs, and immunization service delivery. Results varied across schools and programs and were reflected among the reviewed articles: students in 6 [29] of the 21 studies reported feeling prepared and that their training was adequate [15,17,19,20,22]; students in 7 (33%) of the 21 articles reported a positive impact from the training but highlighted the need for additional training or improvements to the curriculum [16,18,24,26,28,33,34]; students in 7 (33%) of the 21 articles felt they had not received adequate teaching on vaccines; [21,23,27,29,30,32,36] and 1 (5%) article described a comparison of training methods only and did not share results of student preparedness [25].

3.4.2. Short supplemental training—Short supplemental training methods outlined in the reviewed studies were often used to teach an immunization competency using an innovative approach, and/or as a supplemental training method to fill gaps in knowledge and skills following a comprehensive immunization curriculum. Lower-middle-income (4 of 5 articles) and high-income (18 of 35 articles) countries reported using short supplemental training in a variety of ways. The three low-income countries did not report short supplemental training. Methods such as role plays, observing providers' communication with patients, and short, targeted trainings increased nursing, pharmacy, and medical students' knowledge, attitudes, comfort level, and confidence to provide effective counseling and discuss vaccines with hesitant patients. These approaches also increased awareness of vaccine benefits, and the likelihood of recommending vaccines [31,37–49]. Active learning using simulated patients or practical sessions at a training laboratory or clinic improved nursing students' confidence in how to handle adverse reactions during infant vaccination [50]; medical students' performance in vaccine administration [51,52]; and pharmacy students' ability and confidence in determining patient eligibility through screening of vaccination records [19,45,49], vaccine administration [53,54], communicating and counseling patients [16–19,45,49,53,54], addressing vaccine hesitancy [49], and documenting vaccines administered [19,45,49]. Some articles described particular content [e.g., Continuous quality improvement [55], Preferred Cognitive Styles and Decision Making Model [41]] or particular delivery methods [e.g., Virtual Reality [46,56] and Just in Time Training [47]]. Of the articles describing short supplemental training methods, 19 of 22 reported measurable improvement. Short lectures [57], seminars [58] or posting educational fliers and reviewing patient coverage [59] were the short supplemental methods that did not show measurable improvement in three studies.

3.4.3. Both strategies – Short targeted training and immunization curriculum—One article from higher income/upper-middle-income countries used both short, targeted

training and immunization curriculum [48]. The article described the development and implementation of a summer school on vaccinology for medical and nursing students in 19 European countries with a recently developed curriculum on immunization in response to the findings of a gap analysis of the target audience post-immunization curriculum training. Participants reported that they learned a lot from this program, especially from the sessions on communication and practical skills, and they responded positively to the interactive teaching methods/techniques used for delivery.

4. Discussion

The purpose of this systematic review was to synthesize the current literature on immunization pre-service training, including the identification of primary immunization competencies covered, the training methods used, reported outcomes on competencies and behavior change for immunization service delivery, and readiness for immunization practice in both low resource settings and high-income countries. This review highlights regional disparities among published studies (peer-reviewed or grey) that describe immunization pre-service training. Most studies found were conducted in high-income countries [35], with 27 from the United States. Only eight studies came from low- [3] and lower-middle- [5] income countries. Moreover, the reviewed studies targeted only students in academic or health training institutions. There were no studies reporting pre-service training for vaccinators or the immunization workforce from non-academic settings.

Pharmacy, medical/residency, EPI training, and nursing students were the main audiences targeted in the published studies regardless of settings (low-income countries or upper-income countries), with the curricula for pharmacy and medical students being far more represented than that for nursing students. The two studies that targeted nursing students came from high-income countries. Nurses often play various roles (e.g., supervisor, primary vaccinator, or immunization service provider) in most clinic settings, especially in developing countries [60]. Nurses also substitute for doctors in certain urban and rural areas, where they deliver healthcare services with a higher degree of patient satisfaction than doctors [61]. Given the crucial role that nurses play in vaccine service delivery, publishing best practices for pre-service instruction for this group, particularly in low-resource settings, would be a valuable contribution to the literature.

4.1. Immunization competencies in the pre-service curriculum

Results of this review also found that eight of the ten competency domains outlined in the standard immunization framework for the immunization workforce are reported to some degree among the reviewed studies. Using the model suggested in Fig. 1, the standard immunization competencies can be used as a guideline to determine what content is appropriate for pre-service training. Keeping in mind that workers will obtain training when hired, as well as throughout their careers, academic institutions should work with the ministries of health to identify the reasonable proficiency level of specific competencies when a graduate is recruited for employment.

4.2. Training delivery methods

The studies reviewed revealed various training methods and delivery strategies to educate students in health training institutions on immunization and vaccination topics. A blend of delivery methods, including e-learning, traditional classroom, and field-based practice with mentoring could optimize resources and help adequately prepare students for their future responsibilities [62]. The best practices of learning science should be considered when designing a curriculum.

4.3. Measuring and designing for behavior change

Of the 44 reviewed studies, the majority (77%) highlighted methods that were effective in improving knowledge proficiency on immunization topics and other competencies (e.g., addressing patients' concerns, administering vaccines, and responding to AEFI). Improvement in these competencies might be due to teaching techniques and applied learning strategies that used realistic situations (e.g., simulation, role-play, practical labs for vaccine administration/injection skills, etc.). According to the literature on human performance, a learner can better retrieve and apply information and skills on the job if they practice similar situations during training [63]. Hence, it is important to design realistic and active learning strategies to prepare healthcare students for immunization responsibilities in the workplace [63].

4.4. Limitations observed among the studies reviewed

One of the main observations among these studies was the varying quality of evaluation methods used: some studies reported evaluation of short-term trainings on immunization topics and knowledge assessment using short quizzes or the pre-and post-tests. Although this might be an appropriate measurement in academic settings, it is unclear if these methods accurately capture students' practical competency level (i.e., ability to competently apply what they learned in a job). Moreover, 15 studies reported only post-training evaluation results, making it difficult to determine change in the knowledge and skills. Rigorous study design and methods are needed to properly measure short- and long-term impact of pre-service trainings. An additional limitation is the target population under review: as mentioned earlier, studies were mostly done in high-income countries targeting health professional students, with limited focus on nursing students and no focus on vaccinators at lower educational levels.

4.5. Strengths and limitations of this review

This is the first review that comprehensively examined pre-service training interventions for the immunization workforce, including training content, methods, and outcomes. All types of studies related to this topic, regardless of study location and language, were reviewed. This review only focuses on the documentation of pre-service training interventions and outcomes reported. Most of the studies reviewed did not test a hypothesis or provide adequate information about their study methods. The authors could not draw any conclusions on the extent that these topics, methods, and outcomes were covered during pre-service training, including actual learning hours. The authors did not include published conference abstracts with no full report due to difficulty of assessing full scope

of interventions and results. The authors also did not interview principals, faculty members, or students, or perform a desk review of the immunization curriculum from health training institutions. More studies are needed to help understand the current practices, facilitators, and barriers to good pre-service training in resource-limited settings to guide health system strengthening efforts.

Our search strategy was rigorous, yet specific to immunization. Possibly, some articles might have been missed during the database search. To avoid publication bias, we sought grey literature, reached out to experts or institutions for potential reports or articles on pre-service training on immunization, and searched references of retrieved articles and relevant journals for additional articles. To minimize any additional random error or bias, two authors independently reviewed the search results and the articles that met inclusionary criteria, then discussed the selected list of articles and any concerns.

5. Conclusions

Because vaccine-preventable diseases are a key part of the Sustainable Development Goals and a global priority, it is imperative to adequately prepare the immunization workforce of tomorrow, especially with emerging diseases such as COVID-19. This review highlights the following key points: 1) documentation of pre-service training on immunization is mostly based in high-income countries and appears to be non-existent for non-professional students or in non-academic settings; 2) professional healthcare students (e.g., medical, pharmacy, and nursing students) did not always have the expected knowledge on immunization for their level of training, and students did not always feel that they had received adequate teaching on immunization; 3) training methods (e.g., active learning strategies or simulations) that increased student knowledge, skills, and confidence mirror best practices that are found in the literature for adult learning; 4) assessments that measure knowledge, skill, or attitude in realistic settings could help determine students' immunization readiness; 5) eight of the ten recommended immunization competencies were included in the reported curricula to at least some degree. Prioritizing essential target audiences, selecting appropriate content, designing practical training, delivering it via effective training strategies, and evaluating results will help prepare students for the immunization challenges of tomorrow. To meet the Sustainable Development Goals, governments, donors, and partners should commit to quality pre-service immunization training [2]. Achieving the Immunization Agenda 2030 targets and keeping people safe from VPDs depends on a trained, competent, and confident workforce[4].

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Data availability

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

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Fig. 1.

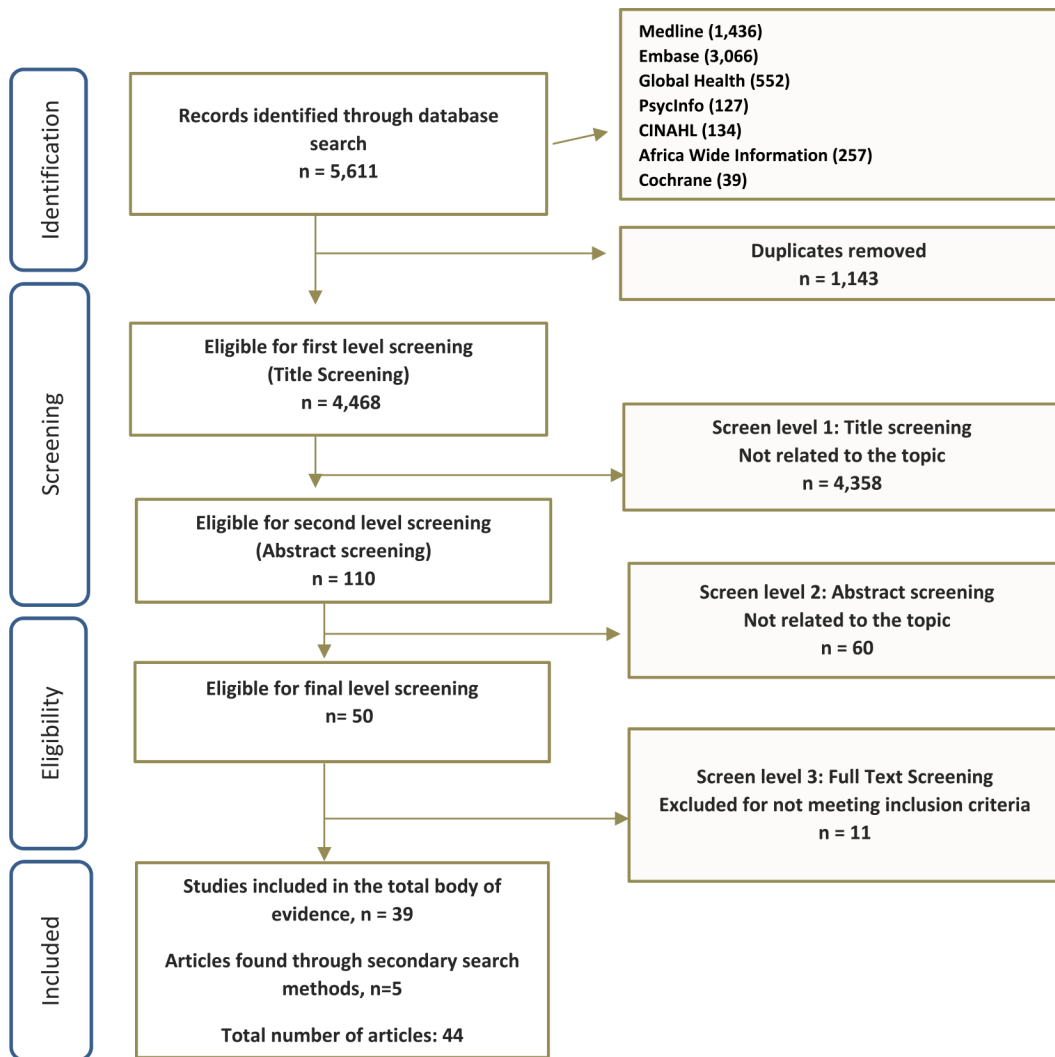


Fig. 2. Review Search Flow Diagram: Pre-service training (2001–2021).

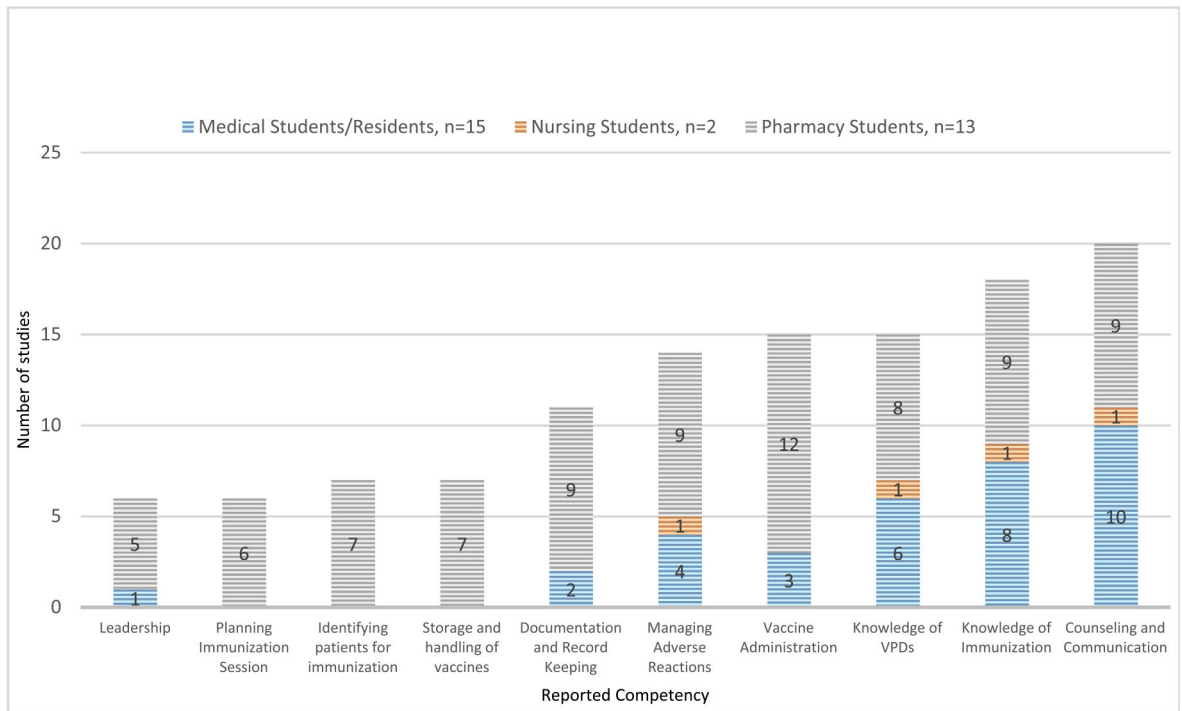


Fig. 3. Competencies covered in medical, nursing, and pharmacy pre-service training, by student type for 30 of 44 articles that reported on competencies covered in training

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Table 1

Population, Intervention, Comparison, and Outcome (PICO) framework.

Population (targeted by the interventions)	In any country, individuals preparing to enter the immunization workforce or provide immunization services.
Interventions	Pre-service training on immunization reported or published in the peer-reviewed or grey literature between January 2001 to November 2021 regardless of study designs and regions
Comparators	No comparators
Outcomes of the studies reviewed	<ul style="list-style-type: none"> • Immunization competencies covered (e.g., injection technique skills/confidence in vaccine administration) • Types of training methods used (e.g., didactic lectures or practical training with simulated patients) • Change in individuals' knowledge, attitudes, and behaviors related to immunization service delivery, immunization counseling, etc. • Individuals' readiness or feeling prepared for immunization practice • Immunization training curriculum development / description / intervention

Table 2

The number of studies and countries reviewed, based on the World Bank categorization.

World Bank income category (number of studies)	Countries (n) represented in the studies reviewed
High-income (35)	Australia (2); Canada (2); France (1); Germany (1); Italy (1); Norway (1); United States (27)
High-income & Upper-middle-income (1) *	Multi-European countries study: Belgium, Bulgaria, Italy, Romania, Slovenia, Spain, and Sweden (1)
Lower-middle-income countries (5)	India (2), Indonesia (1), Nigeria (1), Thailand (1)
Low-income countries (3)	Kenya (1), Malawi (1), Tanzania (1)

* This study was a multi-country study that included both high-income and upper-middle-income countries in Europe.

Table 3

Mapping of the reported competencies covered at health training institutions against the recommended standard competencies for immunization workforce.

Recommended Standard Competencies for Immunization Workforce	Corresponding Reported Competencies Covered at Health Training Institutions in the Reviewed Studies
Management and Leadership	Leadership
Policy, Planning, and Finance	Planning Immunization Session
Vaccination Service Delivery	Identifying Patients for Immunization
Vaccines, Supplies, and Logistics	Storage and Handling of Vaccines
Monitoring, Evaluation, and Data Use	Documentation and Record Keeping
Safety of Vaccines and Immunization	Managing Adverse Reactions
Vaccination Service Delivery	Vaccine Administration
Vaccine Preventable Diseases and Program	Knowledge of VPDs
Vaccine Preventable Diseases and Program	Knowledge of Immunization
Advocacy and Communications	Counseling and Communication
Human Resources and Performance Management	Not Reported
Disease Surveillance, Investigation, and Response	Not Reported

Table 4
Methods used for training interventions, development, and evaluation of curricula by training type and target population (N = 44).

Target population	Short Supplemental Trainings (n = 22)	Immunization Curricula (n = 21)	Short, targeted training and immunization curriculum (n = 1)
Pharmacy Students	<ul style="list-style-type: none"> Practical opportunities to administer vaccinations in clinics [53,54] Active-learning, using simulated patients [19,45,49] Two in time training (JITT) – a condensed 10 min training [47] Two-week vaccine hesitancy learning unit with simulated patients and formal coursework [49] 	<ul style="list-style-type: none"> Comprehensive immunization course – in person lecture + skills laboratory [22] Comprehensive immunization course–online instruction + skills laboratory [24,25] Comprehensive Australian vaccination training program [20] American Pharmacists Association (APhA) training [15–19] Canadian health professional immunization training [23] Pharmacy education at 2 universities in North Dakota [21] 	<p>Medical and nursing school education in Europe & 5-day comprehensive summer school on vaccinology [48]</p>
Medical/Residency Students	<ul style="list-style-type: none"> Review of patient vaccination coverage and educational flyers [59] Continuous quality improvement (CQI) training (didactic lectures and experience leading a CQI team) [55] Comprehensive educational session [31] Short-targeted training focused on addressing a single VPD [37,40] Pediatric clerkship [43] Injection practice on actual humans versus manikins [52] Short immunization training/educational seminar [38,58] A short lecture and email reminders focused on a single VPD [57] Two lectures on counseling skills, videos, and role play [42] Virtual Reality curriculum for stimulating vaccine hesitant patients [46] Training in the Preferred Cognitive Styles and Decision-Making (PCSDM) model [41] Short immunization training followed by practical training/immunization clinic [51] Lectures and simulations [44] 	<ul style="list-style-type: none"> Puerto Rico medical schools and residency programs [30] Medical School Education and Pediatric Residency Training [26] United States Medical School Education [27] Medical education at 2 universities in North Dakota [21] French Medical Education [32] United States Medical training–pediatric residency education [28,29] 	
Nursing Students	<ul style="list-style-type: none"> Simulated anaphylaxis by vaccination in infants [50] Short-targeted training focused on addressing a single VPD [39] 	<ul style="list-style-type: none"> Canadian health professional immunization training [23] Nursing education at 2 universities in North Dakota (Doctor of Nursing practice & Bachelor of Science in nursing) [21] 	<p>Medical and nursing school education in Europe & 5-day comprehensive summer school on vaccinology [48]</p>
EPI staff		<ul style="list-style-type: none"> Kenya's adoption of the WHO EPI prototype curriculum, updated manuals, and 8-week practicum [33] Malawi Immunization training curriculum [34] Nigeria EPI pre-service training institutions [36] Tanzania pre-service training education based off the WHO prototype curriculum and dissemination of updated materials [35] 	

Table 5

Short, targeted training methods and reported outcomes regarding student competencies and behavior change.

Training Method	Country	World Bank Categorization	Population included/assessed	Competencies Measured	Assessment Method	Increase in MEASURED Competencies	Assessment Methods by Competency	Assessment Method 2 (if applicable)	Increase in SELF-RATED Competencies:
Pharmacy Students									
Practical opportunities to administer vaccinations in clinics [54]	Canada	High-income	36 pharmacy students	Measured: Vaccine Administration	20-point checklist	YES	Self-reported: Confidence in vaccine administration	Survey	YES
Practical opportunities to administer vaccinations in clinics [53]	United States	High-income	108 pharmacy students/81 pharmacy students	Measured: Knowledge of immunization	15-point quiz	YES	Self-reported: Confidence in vaccine administration	Likert Scale	Partial (no significant change in confidence scores in the 6 areas of immunization delivery pre/post; however, 5 students reported increased confidence in vaccine administration)
Active-learning using simulated patients [45]	United States	High-income	125 pharmacy students/103 pharmacy students	Measured: Knowledge of immunization	14-point quiz	YES	Self-reported: confidence in determining patient eligibility, communication, managing adverse reactions, documentation	Likert Scale	YES
Just in time training (JITT) for pharmacy students previously certified to administer adolescent and adult vaccinations [47]	United States	High-income	45 pharmacy students/22 assigned to JITT	Measured: Vaccine preparation, administration, documentation, and counseling	20-point scale	Change in competencies not assessed pre/post; only a comparison of training methods post-training	Self-reported: Interest, confidence, and comfort in providing pediatric vaccination in an emergency	Likert Scale (3 questions)	YES
Two-week vaccine hesitancy learning unit - simulated patients and formal coursework [49]	United States	High-income	203 pharmacy students/180 pharmacy students	Measured: Counseling and communication	16 item grading rubric	YES	Self-reported: Confidence in counseling and communication	Attitudes survey (13 items)	YES
Nursing Students									

Training Method	Country	World Bank Categorization	Population included/assessed	Competencies Measured	Assessment Method	Increase in MEASURED Competencies	Assessment Methods by Competency	Assessment Method 2 (if applicable)	Increase in SELF-RATED Competencies:
Simulated anaphylaxis by vaccination in infants [50]	Norway	High-income	30 public health nursing students	–	–	–	Self-reported: Simulation as a positive learning tool for anaphylaxis	Student reflections (800 words)	YES
Short, targeted training focused on addressing a single VPD [39]	United States	High-income	388 nursing students (includes medical students, as well, but see Berenson 2019)	Measured: Knowledge of immunization (dosing schedule and contraindications)	Questionnaire (4 knowledge questions)	YES	Self-reported: Beliefs and attitudes about the importance of vaccination, comfort in counseling patients	Questionnaire (21 questions)	YES
Medical Students									
Virtual Reality curriculum for stimulating vaccine hesitant patients [46]	United States	High-income	24 pediatric residents	–	–	–	Self-reported: Perceived impact on counseling and communication	Survey	YES
Review of patient vaccination coverage and educational flyers [59]	United States	High-income	300 patient charts were evaluated (150 pre- and 150 post-)	Measured: Knowledge of immunization, uptake of patient vaccination	9-point quiz and 150 patient charts pre/post (300 total)	NO	N/A	N/A	N/A
Continuous quality improvement (CQI) training (didactic lectures and experience leading a CQI team) [55]	United States	High-income	1 medical student	Measured: uptake of patient vaccination	Immunization status of children under 2 years	YES	N/A	N/A	N/A
Comprehensive educational session on immunization and practical vaccination program in the first year of medical training [31]	United States	High-income	97 first year medical students	–	–	–	Self-reported: Comfort in counseling and communication, administering the vaccine, perceived importance of immunization	18 question survey	YES
Short, targeted training focused on addressing a single VPD [40]	United States	High-income	276 medical students/256 medical students	Measured: Knowledge of immunization (dosing schedule and contraindications)	Questionnaire (4 knowledge questions)	YES	Self-reported: Beliefs and attitudes about importance of vaccination, comfort in counseling patients	Questionnaire (24 questions)	YES
Pediatric clerkship including observing providers'	United States	High-income	19 medical students	–	–	–	Self-reported: Students' approach	Student narratives on vaccine	YES

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Training Method	Country	World Bank Categorization	Population included/assessed	Competencies Measured	Assessment Method	Increase in MEASURED Competencies	Assessment Methods by Competency	Assessment Method 2 (if applicable)	Increase in SELF-RATED Competencies:
professionalism and communication with patients [43]							to counseling and communication	hesitancy or refusal	
Injection practice on actual humans versus mannequins [52]	Thailand	Lower-middle-income	57 medical students in the control group with mannequin only and 32 medical students in intervention group (using each other as surrogate patients)	Measured: Vaccine Administration	9-point scale	YES	Self-reported: Confidence in vaccine administration, and empathy with patients	Likert Scale (5 item)	YES
Short immunization training/educational seminar [38]	Italy	High-income	118 medical students/81 students	Measured: Immunization Knowledge	Survey	YES	Self-reported: Knowledge and attitudes concerning vaccination	Survey	Yes
A short lecture and email reminders focused on a single VPD [57]	United States	High-income	20 medical students	Measured: Knowledge of immunization, counseling, and communication	Survey	Partial - Knowledge scores increased but no effect on counseling and communication	-	-	-
Two lectures on counseling skills, videos, and role-play [42]	India	Lower-middle-income	38 medical students	Measured: Counseling and communication	Standardized checklist	YES	-	-	-
Short, targeted training focused on addressing a single VPD [37]	United States	High-income	132 medical students/101 medical students	-	-	-	Self-reported: Confidence in counseling and communication, awareness of vaccine benefits	Questionnaire and Likert scale	YES
4-day summer school on vaccinology [48]	Belgium, Bulgaria, Italy, Romania, Slovenia, Spain, and Sweden	High-income/upper-middle-income	36 students	-	-	-	Self-reported: Counseling and communication, vaccine administration, VPD knowledge, Immunization knowledge	Daily evaluation forms, student assessment	YES

Training Method	Country	World Bank Categorization	Population included/assessed	Competencies Measured	Assessment Method	Increase in MEASURED Competencies	Assessment Methods by Competency	Assessment Method 2 (if applicable)	Increase in SELF-RATED Competencies:
Training in the Preferred Cognitive Styles and Decision-Making (PCSDM) model [41]	United States	High-income	82 medical residents	Measured: Knowledge of immunization	10 questions	YES	Self-reported: Confidence in counseling and communication	15 questions	YES
Comparison of vaccination seminars – practice-based and theoretical [58]	Germany	High-income	148 medical students	Measured: Understanding of vaccination certificates	Pre/post test	NO	Self-reported: Confidence in understanding vaccination certificates	Post-test & training evaluation	Students in the practical seminar were significantly more confident than the theoretical seminar
Two step training program – group teaching on knowledge of immunization, followed by practical training [51]	India	Lower-middle-income	30 medical students	Measured: Knowledge of immunization	Pre/post questionnaire	YES	Self-reported: confidence in administering vaccines	Assessment	YES
Comparison of conventional lectures and lectures with simulations [44]	Indonesia	Lower-middle-income	68 medical students in the control group, 68 students in intervention group	Measured: knowledge of immunization & VPDs, counseling and communication, vaccine safety	Questionnaire, and skills assessment	Lectures with simulation had a significant impact on student knowledge and skills			

Table 6

Immunization curricula and reported outcomes on student competencies and behavior change.

Curriculum	Country	WB Categorization	Population included/assessed	Competencies Measured	Assessment Method	Measured competencies increased or adequate	Competencies Self-Reported	Assessment Method	Increase in SELF-RATED Competencies:	Did curriculum prepare students/satisfied?	Gaps in Curriculum/Notes
Pharmacy Students											
American Pharmacists Association's (APhA) Pharmacy-Based Immunization Delivery Program [16]	United States	High-income	454 students/326 students	-	-	-	Self-reported: Confidence in immunization knowledge, vaccine administration, adverse reaction management	11 question survey	-	YES	Some students reported needing additional training on vaccine administration and immunization knowledge.
Comprehensive Immunization course – 8h of didactic lecture and a skills laboratory [22]	United States	High-income	85 students	Measured: Immunization knowledge	19 true/false questions	YES	Self-reported: Immunization knowledge, confidence in vaccine administration and adverse event management	Questionnaire	YES	-	-
Comprehensive Immunization Delivery elective course – online instruction + an in-person practical immunization session on fellow students [24]	Australia	High-income	336 students/286 students	-	-	-	Self-reported: Satisfaction with training, vaccine administration	Questionnaire	-	YES	Some students reported that there was not sufficient time for the pre-reading materials and that there was too much information.
American Pharmacists Association's (APhA) Pharmacy-Based Immunization	United States	High-income	57 students/54 students	-	-	-	Self-reported: Knowledge of immunization, confidence in vaccine administration, confidence in counseling and	Survey - Likert scale questions	-	YES	-

Curriculum	Country	WB Categorization	Population included/assessed	Competencies Measured	Assessment Method	Measured competencies increased or adequate	Competencies Self-Reported	Assessment Method	Increase in SELF-RATED Competencies:	Did curriculum prepare students/satisfied?	Gaps in Curriculum/Notes
Delivery Program [17]							communications, reporting, vaccine storage and management				
Comprehensive Immunization Delivery - RCT of in class to online instruction + an in person practical immunization session [25]	United States	High-income	140 students	Only a comparison of online to in person training. Found no difference in grades between the two.							
APhA, simulation and practical experience in clinics [19]	United States	High-income	127 students				Self-reported: immunization knowledge, confidence in vaccine administration, confidence in counseling and communication, confidence in addressing patient management/needs, confidence in data management/reporting	8 question survey	YES	YES	Each training component was valuable in increasing student confidence.
APhA training [18]	United States	High-income	80 students completed the training	Measured: Immunization knowledge	Final Exam	No pre-test, all students passed the course (>70%)	Self-reported: Learnings from training	Survey	-	YES	14 students reported that some of the information was long, boring, and difficult to retain.
APhA training [15]	United States	High-income		Measured: Knowledge	Self-study quiz and final exam	YES	Self-reported: Confidence in immunization skills	Survey	YES	YES	-

Curriculum	Country	WB Categorization	Population included/ assessed	Competencies Measured	Assessment Method	Measured competencies increased or adequate	Competencies Self-Reported	Assessment Method	Increase in SELF-RATED Competencies:	Did curriculum prepare students/satisfied?	Gaps in Curriculum/ Notes
Vaccination Training Program (VTP) in Australia using online and in-person learning [20]	Australia	High-income	52 master's level and bachelor's level pharmacy students	Measured: Immunization knowledge, knowledge of VPDs, vaccine administration, handling adverse reactions, storage & handling, documentation	Knowledge assessment and skills assessment	YES	Self-reported: Knowledge of vaccination, confidence in vaccine administration, usefulness of training	Likert scale questionnaire	YES	YES	
Mixed Population - nursing, pharmacy & medical											
Canadian nursing, pharmacy and medical schools [23]	Canada	High-income	147 students responded to the survey. Nursing students (39%), pharmacy students (79.6%), and medical students (35%).	Measured: Immunization knowledge, vaccine indications/contraindications, adverse events, and safety	21 questions	NO (knowledge scores averaged 53% to 78% across programs) no pre-test	Self-reported: perceived adequacy of training, comfort in counseling & communication	56 Questions	-	NO	Only 21% of the respondents felt they had received adequate training on vaccines: 16% reported feeling comfortable talking to parents about vaccine concerns.
Medical and nursing school education in Europe [48]	Belgium, Bulgaria, Italy, Romania, Slovenia, Spain, and Sweden	High-income/ Upper-middle-income	184 students and 92 curriculum managers	-	-	-	Self-reported: VPD knowledge, vaccine safety, counseling and communication, vaccine administration, documentation and reporting, storage, and handling of vaccines	Survey	-	NO	85% of the medical students and 87% of nursing students expressed the need for more training on immunization.
Medical, pharmacy and nursing education at 2 U.S.	United States	High-income	223 students - 75 medicine, 52 pharmacy, 96 nursing	Measured: knowledge of immunization	Survey	NO	Self-reported: vaccine knowledge, the likelihood to recommend	Survey		NO	Students did not have the expected knowledge and felt unprepared

Curriculum	Country	WB Categorization	Population included/assessed	Competencies Measured	Assessment Method	Measured competencies increased or adequate	Competencies Self-Reported	Assessment Method	Increase in SELF-RATED Competencies:	Did curriculum prepare students/satisfied?	Gaps in Curriculum/Notes
universities in the Midwest [21]							vaccines, confidence in addressing vaccine related topics, education received				to address vaccine-related discussions.
Medical Students											
Puerto Rico Medical School and Residency Training [30]	United States	High-income	376 students	Measured: Immunization knowledge - vaccine indications, contraindications, and misconceptions	Survey	NO (students did not have the knowledge expected; mean knowledge score was 61% across the students and residents)	-	-	-	-	-
Medical School Education and Pediatric Residency Training [26]	United States	High-income	86 students	-	-	-	Self-reported: Perceived severity of VPDs, confidence in counseling & communication, and the impact of educational strategies	Online survey	-	NO	55.9% of the students felt they had received adequate education on VPD and vaccines during medical school; 73.2% reported having received adequate VPD training during residency.
Year in medical school in the US [27]	United States	High-income	194 students	Measured: Immunization knowledge	Survey	NO (Estimated mean knowledge scores for second, third, and fourth year students of 55% (SD 13), 65% (SD 13), and 74% (SD 10), respectively)	Self-reported: confidence in counseling and communication, immunization knowledge	Survey	-	NO	29% of the students surveyed felt their vaccination education in medical school was adequate.

Curriculum	Country	WB Categorization	Population included/assessed	Competencies Measured	Assessment Method	Measured competencies increased or adequate	Competencies Self-Reported	Assessment Method	Increase in SELF-RATED Competencies:	Did curriculum prepare students/satisfied?	Gaps in Curriculum/Notes
French Medical Education and clinical placements [32]	France	High income	2,118 students	Measured: Immunization knowledge	Survey	NO (mean knowledge score was 58%)	Self-reported: Immunization knowledge, VPD knowledge, counseling and communication, practical administration	Survey	-	NO	Nearly 1/3 of medical students felt underprepared to address adverse events, vaccine hesitancy/patient communication.
Residency training (patient based/experimental teaching) [28]	United States	High-income	34 pediatric residents for cross-sectional longitudinal had 11 residents across the three years.	Measured: Immunization knowledge	Survey	Partial (knowledge scores increased between year 1 and 2 of training, but not between years 2-3. Room for knowledge scores to increase.)	-	-	-	-	-
Medical school training on counseling/communication [29]	United States	High-income	303 medical residents	-	-	-	Self-reported: Knowledge of immunization, counseling, and communication	Survey	-	NO	83.8% of the students wanted more education on risk communication.
EPI Training Institutions											
Expanded Programme on Immunization Pre-service Training Initiatives in Western Kenya and the WHO EPI prototype curriculum, updated manuals, and 8 week practicum [33]	Kenya	Low-income	29 nurse graduates	Measured: Immunization knowledge, communication and counseling, storage and handling, vaccine administration, immunization schedule, documentation and reporting	Explanations and observation	Partial (nursing graduates performed well across immunization practices except checking the vaccine vial monitor (VVM), checking the expiry date, and communicating possible side effects;	-	-	-	-	-

Curriculum	Country	WB Categorization	Population included/assessed	Competencies Measured	Assessment Method	Measured competencies increased or adequate	Competencies Self-Reported	Assessment Method	Increase in SELF-RATED Competencies:	Did curriculum prepare students/Students satisfied?	Gaps in Curriculum/Notes
Malawi Immunization training curriculum [34]	Malawi	Low-income	Eight primary health care (PHC) training centers, three nursing schools, one medical school, and one environmental training school	-	-	immunization knowledge was mixed)	-	Self-reported: Principals' perceived competence of immunization graduates	-	Partial	75% of the principals believed the competence of the graduates to be excellent or very good but 50% reported that time allocated for training was inadequate and there was a need for additional training on a variety of topics.
Tanzania pre-service training education based off the WHO prototype curriculum and dissemination of updated materials [35]	Tanzania	Low-income	21 EPI tutors	-	-	-	-	Self-reported: Program evaluator's perceived preparedness of medical students, public health officers and nurses for vaccine policy, strategies, and technologies for vaccination	-	YES	Medical students, public health officers and midwives are better equipped.
Nigeria EPI pre-service training institutions [36]	Nigeria	Lower-middle-income	62 EPI tutors	Measured: Immunization knowledge of EPI tutors	Questionnaire	NO	-	-	-	-	The survey revealed that immunization knowledge was generally inadequate among EPI tutors in

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Curriculum	Country	WB Categorization	Population included/ assessed	Competencies Measured	Assessment Method	Measured competencies increased or adequate	Competencies Self-Reported	Assessment Method	Increase in SELF-RATED Competencies:	Did curriculum prepare students/ Students satisfied?	Gaps in Curriculum/ Notes
											training institutions.

- Indicates where data was not reported.