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Integrating Sustainable Development Goals into medical education: knowledge, attitudes, and training needs — a systematic review with a focus on Uzbekistan

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Systematic Review

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Abstract

Background

The integration of the United Nations Sustainable Development Goals (SDGs) into medical education is essential for preparing a health workforce capable of addressing the interconnected challenges of climate change, health inequity, and environmental degradation. Despite growing global momentum, the evidence base on SDG-related knowledge, attitudes, and educational needs among medical students remains fragmented and geographically uneven. This review aimed to synthesise the global literature on SDG integration in medical and health professions education, critically examine documented knowledge, attitudes, and training needs, and assess the specific context of the Republic of Uzbekistan.

Methods

A systematic search of PubMed, Scopus, Web of Science, and Google Scholar was conducted for studies published between January 2015 and May 2025. Eligibility criteria included empirical research or reviews addressing SDG-related knowledge, attitudes, or educational interventions among undergraduate or graduate health professions students. A total of 148 full-text articles were assessed; 27 core studies were included in the final synthesis, supplemented by grey literature and institutional documents from Uzbekistan.

Results

The review identified a consistent "awareness-knowledge gap" across settings: students express high concern about climate change and positive attitudes toward sustainability, yet demonstrate limited specific knowledge of the SDGs and their clinical relevance. Effective pedagogical strategies include problem-based learning, team-based learning, simulation, and interdisciplinary approaches. Persistent barriers include curriculum overload, insufficient faculty training, limited institutional support, and the concentration of research in high-income countries. In Uzbekistan, institutional commitments to SDG integration are documented at leading medical universities, but no peer-reviewed empirical studies assessing students' knowledge or attitudes were identified. This represents a critical evidence gap.

Conclusions

Medical education must prioritise the systematic integration of SDG competencies through evidence-based pedagogical strategies. The absence of empirical data from Uzbekistan highlights the need for context-specific research to inform curriculum reform. The present study provides the first comprehensive review of the global landscape with a dedicated analysis of the Uzbekistani context, establishing a foundation for future educational interventions.

Background

The Sustainable Development Goals (SDGs), adopted by all United Nations Member States in 2015, constitute a universal framework comprising 17 goals and 169 targets designed to address the world's most pressing challenges by 2030, including poverty, inequality, health, climate change, and environmental degradation [1]. Health occupies a central position within this framework: SDG 3 explicitly aims to "ensure healthy lives and promote well-being for all at all ages," while virtually all other SDGs influence and are in turn influenced by health outcomes [2].

Healthcare professionals are positioned at the frontline of both responding to the health impacts of global environmental and social challenges and contributing to the environmental footprint of healthcare delivery. The global healthcare sector accounts for approximately 4.2% to 4.6% of total greenhouse gas emissions [3, 4]. This dual reality — the health system's vulnerability to environmental determinants of health and its own contribution to environmental degradation — has generated urgent calls for the fundamental transformation of health professions education [5].

The World Health Organization (WHO) has identified a "climate-smart health workforce" as one of ten core pillars of climate-resilient and low-carbon health systems in its Operational Framework (updated 2023) [6]. This framework mandates that health professionals acquire competencies not only in clinical care but also in environmental sustainability, systems thinking, and interprofessional collaboration to address the complex nexus of health and sustainable development. The AMEE Consensus Statement on planetary health and education for sustainable healthcare has further articulated core competency domains for health professions education, emphasising that sustainability education should be mandatory, integrated throughout curricula, and assessed using authentic methods [7].

Despite these international mandates, progress in integrating SDG-related content into medical curricula remains uneven. A 2025 scoping review by Maisoon and colleagues documented that the integration of climate change and health components into medical education commenced only around 2018, with initiatives heavily concentrated in North America and Europe [8]. The 2023 Lancet Countdown report indicated that fewer than 15% of countries had incorporated climate-health education into medical curricula, with particularly low uptake in low- and middle-income countries (LMICs) [9]. A global systematic scoping review published in 2025 identified that among 73 studies on planetary health education, 88% originated from high-income countries, revealing a profound geographic imbalance in evidence generation [10].

Furthermore, an Environmental Scan of planetary health curricula conducted between 2022 and 2025 found that 77.02% of identified courses were in countries ranked among the top 10 global emitters, while none were located in the countries most vulnerable to climate change impacts [11]. This inequitable distribution of educational resources represents a significant global health justice concern.

The Republic of Uzbekistan presents a particularly relevant case for examining SDG integration in medical education. As a lower-middle-income country in Central Asia facing significant climate-related

health challenges — most notably the ongoing health and environmental consequences of the Aral Sea ecological disaster — Uzbekistan has articulated institutional commitments to the SDGs and is undertaking substantial health workforce reforms [12]. The number of students admitted to medical universities has increased 4.5-fold over seven years, and a 2025 presidential decree mandated the creation of a transparent assessment system for medical graduates involving international expertise [13]. Leading medical universities, including Tashkent Medical Academy, Tashkent State Medical University, and Samarkand State Medical University, have publicly declared their integration of SDG content into curricula [14, 15, 16]. However, no peer-reviewed empirical studies have assessed the actual knowledge, attitudes, or educational needs of Uzbekistani medical students regarding the SDGs.

The objectives of this review were threefold: (1) to systematically synthesise the global empirical evidence on knowledge, attitudes, and educational needs of health professions students regarding the SDGs and planetary health; (2) to critically analyse documented educational interventions and pedagogical strategies for SDG integration, identifying barriers and facilitators; and (3) to provide a dedicated analysis of the Uzbekistani context, identifying specific evidence gaps that justify targeted empirical research.

Methods

Search strategy

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [17]. A comprehensive search was performed in the following electronic databases: PubMed (MEDLINE), Scopus, Web of Science Core Collection, and Google Scholar. The search was conducted between January and May 2025.

The search strategy combined controlled vocabulary (MeSH terms where applicable) and free-text keywords using Boolean operators: ("Sustainable Development Goals" OR "SDG" OR "planetary health" OR "climate change and health" OR "environmental sustainability") AND ("medical education" OR "nursing education" OR "health professions education" OR "curriculum" OR "training" OR "competencies") AND ("knowledge" OR "attitudes" OR "perceptions" OR "awareness" OR "educational needs" OR "practices").

Geographic search filters included terms for specific countries and regions: "Uzbekistan," "Kazakhstan," "Russia," "Central Asia," "India," "China," "Japan," "Germany," "United Kingdom," "United States," "Europe," "low- and middle-income countries," and "global."

The search was limited to publications from January 2015 to May 2025, coinciding with the adoption of the SDGs. Languages were restricted to English, Russian, and German. The full electronic search strategy for PubMed is provided in Additional File 1.

Eligibility criteria

Studies were included if they met the following criteria: (a) empirical research (quantitative, qualitative, or mixed-methods designs), systematic or scoping reviews, or descriptive reports of educational interventions with evaluative components; (b) target population of undergraduate or graduate students in medicine, nursing, or allied health sciences; (c) focus on knowledge, attitudes, awareness, practices, competencies, or educational needs related to SDGs, planetary health, climate change and health, or environmental sustainability in healthcare; (d) publication in peer-reviewed journals or official institutional/governmental documents with substantive data; (e) publication between 2015 and 2025.

Exclusion criteria were: studies focusing exclusively on environmental sustainability of university campuses without educational components; non-peer-reviewed opinion pieces, editorials, or commentaries without empirical grounding; conference abstracts without full-text availability; and duplicate publications of the same dataset. For the Uzbekistan-specific section, grey literature including official university reports and policy documents was included selectively given the recognised paucity of peer-reviewed empirical studies.

Study selection and data extraction

Two reviewers independently screened titles and abstracts of all identified records against the eligibility criteria. Full texts of potentially eligible studies were retrieved and independently assessed. Disagreements were resolved through discussion with a third reviewer.

A standardised data extraction form was developed and piloted. Extracted data included: study characteristics (author, year, country, design, sample size), participant characteristics (discipline, level of study), main outcome measures (knowledge, attitudes, practices, educational needs), intervention characteristics (where applicable), key findings, and documented barriers and facilitators. For reviews, the scope, number of included studies, and main conclusions were extracted.

Quality assessment

The methodological quality of included empirical studies was assessed using the Mixed Methods Appraisal Tool (MMAT) version 2018 [18], which enables concomitant appraisal of quantitative, qualitative, and mixed-methods studies. For systematic reviews, the AMSTAR 2 tool was employed [19]. Quality assessment was performed independently by two reviewers, with discrepancies resolved through consensus. Studies were not excluded based on quality scores; rather, quality assessments informed the interpretation and weighting of findings.

Data synthesis

A thematic synthesis approach was employed [20]. Findings from included studies were coded inductively, and codes were grouped into descriptive themes, which were subsequently developed into

analytical themes addressing the review objectives. Given the heterogeneity of study designs, populations, and outcome measures, a meta-analysis was not appropriate. Findings are presented narratively, organised by thematic categories.

Results

Study selection

The initial database search yielded 2,330 records. After removal of duplicates (n = 412), 1,918 records underwent title and abstract screening. Of these, 1,770 were excluded as not relevant to the review objectives. Full texts of 148 articles were assessed for eligibility. Following full-text review, 27 core studies met all inclusion criteria and were included in the final synthesis. Additionally, 15 supporting references and 8 institutional documents from Uzbekistan were incorporated to inform the contextual analysis. The PRISMA flow diagram is presented in Fig. 1.

Study characteristics

The characteristics of included studies are summarised in Table 1. The 27 core studies comprised: 14 cross-sectional surveys, 4 qualitative studies, 5 mixed-methods studies, 3 systematic/scoping reviews, and 1 Delphi consensus study. Geographically, studies originated from: Europe (n = 11, including United Kingdom, Sweden, Germany, Italy, Portugal, Spain, and multi-country European studies), Asia (n = 7, including China, India, Taiwan, Bangladesh, and Lebanon), Africa (n = 4, including Nigeria, Rwanda, Zimbabwe, and South Africa), North America (n = 2, United States and global), multi-regional (n = 2), and Central Asia/Kazakhstan (n = 1). No empirical studies from Uzbekistan, Russia, or other Central Asian countries (excluding Kazakhstan) were identified.

Thematic findings

Theme 1: The awareness-knowledge gap

A consistent finding across studies was the significant discrepancy between students' general awareness of sustainability as a societal concern and their specific, actionable knowledge of the SDGs and their relevance to professional practice.

Álvarez-Nieto et al. (2022) examined nursing students' attitudes toward climate change and sustainability using the validated Sustainability Attitudes in Nursing Survey (SANS_2) across five countries (N = 846) [21]. Students demonstrated consistently positive attitudes toward inclusion of sustainability in curricula (M = 5.47, SD = 1.05 on a 1–6 scale). However, the authors noted that students independently sought information, "not receiving it sufficiently within the formal curriculum."

An Italian study at the University of Magna Graecia (2025) surveyed 638 medical students and residents [22]. While 95% expressed concern about climate-health impacts and 89% acknowledged professional responsibility for reducing healthcare pollution, 12% had never encountered the term "ecological footprint," and 28% had studied sustainability independently outside formal education. Female gender, older age, and postgraduate status predicted higher concern levels.

Carvalhais et al. (2025) conducted an exploratory survey of 247 Portuguese allied health students [23]. Friedman tests revealed significant variability in ratings of knowledge, responsibility, and curricular exposure across sustainability dimensions ($\chi^2(4) = 456.32$, $p < 0.001$). Students identified priority curricular themes including health system environmental impact and recognised strong alignment with SDG 3 (Good Health and Well-being) and SDG 13 (Climate Action).

Shehu and Shehu (2018) reported that among 171 Nigerian clinical medical students, 82.46% were aware of the SDGs, yet only 15.20% knew the correct number of goals, 7.60% the number of targets, and 0.58% the number of indicators [24]. Knowledge of the launch year (16.96% correct) and duration (17.54%) was similarly poor. Encouragingly, 71.93% agreed that SDGs should be taught in universities, and 79.53% expressed willingness to learn.

The Swedish mixed-methods study by Niemi et al. (2025) surveyed 294 nursing and medical students and conducted five focus group discussions and nine individual interviews [25]. Survey findings showed that 63% of students perceived insufficient learning about SDGs and Agenda 2030; 63% believed these topics should constitute a larger curricular component. Qualitative analysis revealed that "the SDGs may be more relevant for healthcare practice than students initially thought, but the education they had received was in most places superficial, or not tied to the SDGs."

Chen and Price (2020) compared 69 Chinese and 32 English nursing students using SANS_2 and focus groups [26]. Chinese students rated the importance of including climate change topics significantly higher than British counterparts. Qualitative analysis identified four themes: conceptual understanding limited to environmental aspects and clinical waste; preferred teaching methods; assessment approaches; and facilitating factors for curriculum integration.

The global study by Hawkins et al. (2024) extended these findings to practicing nurses [27]. The majority of registered nurses from multiple countries perceived themselves as lacking SDG knowledge. Most desired further information, including actionable steps to contribute to goal achievement. Younger nurses (< 50 years), those in the United States, and those in clinical or community settings reported lower SDG knowledge scores.

The study by Schwerdtle et al. (2026) in Lebanon examined knowledge, attitudes, and practices (KAP) among 24 primary healthcare professionals [28]. Participants demonstrated general awareness of climate-related health risks but limited understanding of systemic drivers. Nearly all reported no prior training on climate change and health yet expressed strong interest in flexible, practice-oriented learning.

The authors concluded that "embedding climate change and health competencies into health workforce development — through locally adapted, scalable training programs — is needed."

Darvajkar et al. (2025) assessed 199 Ayurveda interns across 31 Indian colleges [29]. While 80.4% supported mandatory research methodology education and 83.4% endorsed evidence-based Ayurveda research, self-assessed knowledge revealed that only 44.2% considered their contemporary research methodology understanding "good." Barriers included time constraints (68.8%), insufficient motivation (79.4%), mentorship gaps (69.8%), and limited funding awareness (75.9%).

Theme 2: Educational interventions and pedagogical strategies

Multiple studies documented effective pedagogical approaches for SDG integration, though rigorous evaluations of long-term impact remain scarce.

The global systematic scoping review in BMC Medical Education (2025) analysed 73 studies on planetary health education [10]. Only 14 (19.2%) were explicitly focused on planetary health; the remainder addressed climate change (n = 14), sustainable development (n = 12), environmental health (n = 8), and One Health (n = 6), indicating conceptual fragmentation. Teaching formats were predominantly in-person (59%), followed by hybrid (29%) and virtual (12%). Target competencies comprised transversal skills (complex problem-solving, systems thinking, interdisciplinary collaboration) and specific competencies (climate-health interactions, pollution-health relationships).

The scoping review by Maisoon et al. (2025) documented integration of climate-health components in 22 medical schools: 10 in the United States, 4 in Germany, 3 in Australia, and single schools in the United Kingdom, Norway, Netherlands, Canada, and Austria [8]. Integration began around 2018 with a peak in 2020–2021. Student activism catalysed curricular change in 8 of 22 schools (36%). Content addressed sustainable healthcare, health sector climate impact, climate-smart healthcare, and SDG connections.

Badawy and Shaban (2024) conducted a rapid review of 14 studies on pedagogical strategies for SDG 13 integration in nursing education [30]. Problem-based learning, scenario-based simulation, and interdisciplinary collaboration were identified as effective. Barriers included limited faculty training, curriculum overload, and insufficient institutional support.

Yang, Liu, and Hsieh (2022) experimentally compared team-based learning (TBL) with traditional learning among 99 Taiwanese nursing students in a community health course addressing SDG 3 [31]. The TBL group participated in 180-minute weekly sessions for six weeks. Post-intervention, the TBL group scored significantly higher in community health assessment skills, communication, problem-solving, and self-efficacy. Mean posttest community understanding for TBL was 4.04 (SD = 0.52) versus 3.04 (SD = 0.60) for controls ($t = 11.591$, $p < 0.001$).

The Delphi study by Levett-Jones et al. (2024) achieved international expert consensus on essential knowledge and skills for nursing students to promote planetary health [32]. Of 49 proposed statements,

44 (90%) reached ≥ 75% consensus, and 26 (53%) attained ≥ 80%. The final competency set encompassed planetary health knowledge, mitigation and adaptation strategies, and sustainable healthcare implementation skills.

Ago et al. (2025) conducted a qualitative document analysis of environmental sustainability (ES) in medical radiation science (MRS) education [33]. Analysis of 11 documents yielded three themes: current ES practices (teaching, learning, research, and ethical/professional training aligned with regulatory standards), barriers (insufficient knowledge and awareness, limited capacity in funding, resources, and time), and improvement strategies (awareness-raising through planetary health concepts, adoption of ES-oriented pedagogies including problem-based learning, case studies, and rubrics).

Turatsinze et al. (2026) evaluated medical imaging students' perspectives in Rwanda, identifying the "Rwandan Sustainability Paradox" [34]: 88% considered ES very important, yet only 11.6% perceived extensive curriculum coverage. Lectures dominated (66%), while problem-based learning was minimal (20%). Students identified limited digital infrastructure (65%), outdated equipment (47%), and inadequate waste disposal (47%) as primary constraints. Interactive workshops (77%) and integrated modules (69%) were the preferred strategies.

The AMEE Consensus Statement by Shaw et al. (2021) outlined core competencies across three domains: knowledge (interdependence of human health and natural systems), skills (applying sustainability principles to clinical decision-making), and attitudes (commitment to advocacy and stewardship) [7]. The statement emphasised that education for sustainable healthcare should be mandatory, integrated throughout curricula, and assessed authentically.

The Council of Deans of Health (2023) in the United Kingdom provided guidelines for integrating sustainable healthcare education into allied health pre-registration curricula [35]. Five foundational areas and six guiding principles were articulated: outcome-based design, pedagogical diversity, authentic assessment, progressive complexity, interprofessional learning, and alignment with professional standards.

Theme 3: Barriers to SDG integration

Barriers to SDG integration were identified at multiple levels:

Institutional barriers

Curriculum overload was consistently cited as a primary obstacle [30, 34]. The addition of new sustainability content competes with existing, often mandated, biomedical and clinical content. Limited faculty training and expertise in planetary health and sustainability science were highlighted [33, 36]. Insufficient institutional leadership support and absence of strategic mandates for SDG education were also noted [10, 35].

Resource barriers

In LMICs, resource constraints were particularly acute. Studies from Rwanda, Zimbabwe, and Zambia documented limited digital infrastructure, outdated clinical equipment, inadequate waste disposal facilities, and insufficient teaching materials as barriers to both teaching and implementing sustainable practices [33, 34, 37].

Systemic barriers

At the national level, absence of policy mandates and accreditation requirements for SDG competencies limits systemic integration [8]. The Environmental Scan of planetary health curricula found that courses were concentrated in high-emitting countries, while none existed in the most climate-vulnerable nations [11]. This inequitable distribution was described as "a finding of profound inequity" by the authors.

Cultural and perceptual barriers

Resistance to change among staff (41.1% in the Portuguese study) and perceptions that sustainability is outside the scope of clinical practice were documented [23, 34]. Students' lack of confidence in applying sustainability principles clinically reflected insufficient practical training opportunities [25].

Theme 4: The Central Asian and Uzbekistan context

Kazakhstan

The only empirical study identified from Central Asia was the qualitative investigation by Cruz et al. (2024) conducted within the "Qaz Green Health Project" [38]. This study explored perspectives of nursing, medical, and public health students regarding environmental sustainability in healthcare. Students recognised the importance of sustainability but demonstrated significant competence deficits. The research was part of a broader project (May 2023 – December 2025) aimed at developing environmental sustainability competencies in health professions education.

Russia

No peer-reviewed empirical studies measuring SDG knowledge or attitudes among Russian medical students were identified in the literature search. The topic appears to be addressed only within general courses such as life safety and hygiene, without systematic linkage to the global SDG framework. This represents a substantial evidence gap given Russia's influence on medical education systems across the Commonwealth of Independent States.

Uzbekistan

The search identified institutional declarations but no peer-reviewed empirical studies. Tashkent Medical Academy has documented SDG-related education through problem-based learning, monthly seminars on sustainable healthcare, an "SDG Ambassadors" student programme, and research grants targeting SDG topics [14]. Tashkent State Medical University reports integration of SDG content into core public health

courses and collaboration with WHO and UNDP on comparative research [15]. Samarkand State Medical University holds an annual SDG conference and regional roundtable discussions [16]. Westminster International University in Tashkent participates in the Times Higher Education Impact Rankings, which assess university contributions to the SDGs [39].

Uzbekistan has committed to the WHO Alliance for Transformative Action on Climate and Health (ATACH), which obligates member states to develop climate-resilient health systems, including workforce training. However, no documented evidence of specific educational interventions resulting from ATACH participation was identified.

Multiple UN agencies are active in Uzbekistan: WHO supports health system strengthening, UNICEF collaborates on maternal and child health, and UNDP assists with SDG governance and institutional capacity building [40]. However, none of these partnerships have generated published research on SDG-related knowledge or attitudes among medical students.

The critical evidence gap

The complete absence of peer-reviewed empirical studies from Uzbekistan measuring SDG knowledge, attitudes, or educational needs among medical students constitutes a significant research gap. This limits the capacity to

- Benchmark Uzbekistani medical students' SDG literacy against international comparators
- Identify specific knowledge gaps and attitudinal patterns to inform targeted curriculum interventions
- Document student preferences for SDG education content and delivery methods
- Contribute to the regional Central Asian evidence base

Discussion

This systematic review synthesised evidence from 27 core studies on the integration of SDGs into medical and health professions education, supplemented by institutional documents from Uzbekistan. The findings reveal several consistent patterns, critical gaps, and implications for future research and educational practice.

The persistent awareness-knowledge gap

The most consistent finding across diverse geographical, cultural, and economic contexts is the gap between students' general environmental awareness and their specific SDG knowledge. This gap was documented in high-income European countries [21, 22, 25], Asian nations [26, 29], and African settings [24, 34], suggesting it is a systemic feature of current health professions education rather than a context-specific anomaly.

The theory of planned behaviour [41] offers a useful explanatory framework: while attitudes toward sustainability are predominantly positive, subjective norms and perceived behavioural control may be insufficient to translate favourable attitudes into sustainable clinical behaviours. The study by Leal et al. (2024) demonstrated that sustainability knowledge influences behaviour partially through the mediating role of attitudes, underscoring that educational interventions must target all components of the intention-behaviour pathway, not merely knowledge transmission [42].

Effective pedagogical strategies and their limitations

The reviewed literature identifies problem-based learning, team-based learning, simulation, and interdisciplinary approaches as promising pedagogical strategies for SDG education [10, 30, 31, 33]. These active learning methods align with established principles of adult learning theory and have demonstrated effectiveness in improving short-term knowledge and attitudes. The experimental study by Yang et al. [31] provides the strongest evidence for TBL effectiveness in the SDG context, though its single-institution design limits generalisability.

However, the evidence base suffers from significant limitations. Most studies assess outcomes immediately post-intervention without longitudinal follow-up. The absence of rigorous, multi-institutional randomised controlled trials limits the capacity to make evidence-based recommendations for specific pedagogical approaches. Furthermore, no studies have assessed the impact of SDG education on actual clinical practice behaviours or patient outcomes — the ultimate indicators of educational effectiveness.

The global inequity in evidence generation

A profoundly concerning finding is the concentration of SDG education research in high-income countries, while the nations most vulnerable to climate-related health impacts remain unstudied. The Environmental Scan documenting that no planetary health courses exist in the most climate-vulnerable countries represents a global health education injustice [11]. This inequity perpetuates a cycle wherein the health professionals serving populations at greatest risk from climate change receive the least preparation for addressing climate-related health challenges.

The absence of research from Uzbekistan and most of Central Asia exemplifies this gap. As a country facing the health consequences of the Aral Sea environmental crisis, air quality concerns in industrial centres, and the double burden of communicable and non-communicable diseases — all interconnected with SDG targets — Uzbekistan urgently needs an evidence base to guide educational reform.

Implications for Uzbekistan

The institutional commitments documented at Tashkent Medical Academy, Tashkent State Medical University, and Samarkand State Medical University indicate recognition at the leadership level of the importance of SDG integration [14, 15, 16]. However, in the absence of empirical data on student knowledge, attitudes, and needs, these initiatives risk being designed without adequate understanding of their target population.

Several specific contextual factors in Uzbekistan warrant consideration in future research and curriculum development. First, the post-Soviet educational legacy, characterised by teacher-centred pedagogies and discipline-based (rather than integrated) curricula, may influence both student receptivity to active learning methods and faculty capacity to implement them. Second, the traditional cultural context and the role of religious values (Uzbekistan is a predominantly Muslim country) may shape attitudes toward certain SDG-related topics, including sexual and reproductive health (SDG 3.7, SDG 5.6) and gender equality (SDG 5). Third, resource constraints — particularly in rural medical institutions — may limit the feasibility of simulation-based and technology-intensive pedagogical approaches.

Future research in Uzbekistan should employ validated instruments such as the SANS_2 [21] or the Sustainability Consciousness Questionnaire [42] to enable international comparisons. Mixed-methods designs that combine quantitative surveys with qualitative exploration of contextual factors would provide the rich data necessary for culturally appropriate curriculum development. Intervention studies should employ quasi-experimental or randomised designs with longitudinal follow-up to generate evidence of effectiveness that can inform policy.

Strengths and limitations of this review

This review has several strengths. It employed a systematic search strategy across multiple databases, adhered to PRISMA guidelines, and included studies from diverse geographical and economic contexts. The dedicated focus on Uzbekistan, informed by grey literature and institutional documents, provides a contextual analysis not available in previous reviews.

Limitations should be acknowledged. The restriction to English, Russian, and German languages may have excluded relevant studies published in other languages, particularly Chinese. The heterogeneity of included studies precluded meta-analysis. Quality assessment revealed variability in methodological rigour; several studies employed convenience sampling and self-reported measures subject to social desirability bias. The Uzbekistan-specific analysis relied substantially on institutional documents rather than peer-reviewed research, reflecting the evidence gap this review identifies.

Conclusions

This systematic review demonstrates that while health professions students globally express high concern about sustainability and positive attitudes toward SDG integration, their specific knowledge remains fragmented and insufficient for translating awareness into professional competence. Effective pedagogical strategies exist but lack rigorous evaluation, particularly regarding long-term practice impact. The concentration of research in high-income countries and the absence of studies from climate-vulnerable nations represent a critical global health education inequity.

For Uzbekistan, this review identifies a foundational evidence gap: no empirical studies have assessed medical students' SDG knowledge, attitudes, or educational needs. Addressing this gap through methodologically rigorous, contextually appropriate research is essential to inform the curriculum

reforms that Uzbekistani medical universities have committed to undertaking. Such research would not only benefit Uzbekistan but would contribute to building the regional Central Asian evidence base and to addressing the global inequity in SDG education research.

The findings support several recommendations for policy and practice: (1) medical schools should integrate SDG competencies as a mandatory, spiralled component of curricula rather than optional electives; (2) faculty development programmes in planetary health and sustainability science should be prioritised alongside student education; (3) national accreditation bodies should include SDG competencies in medical education standards; (4) research funding should be directed toward SDG education research in LMICs, particularly in understudied regions including Central Asia; and (5) international collaborations should support capacity building for SDG education research and curriculum development in settings like Uzbekistan.

Abbreviations

• **ATACH**
Alliance for Transformative Action on Climate and Health
• **ES**
Environmental Sustainability
• **KAP**
Knowledge, Attitudes, and Practices
• **LMICs**
Low- and Middle-Income Countries
• **MRS**
Medical Radiation Sciences
• **PBL**
Problem-Based Learning
• **PRISMA**
Preferred Reporting Items for Systematic Reviews and Meta-Analyses
• **SANS_2**
Sustainability Attitudes in Nursing Survey (version 2)
• **SDGs**
Sustainable Development Goals
• **TBL**
Team-Based Learning
• **UNDP**
United Nations Development Programme
• **WHO**
World Health Organization

Declarations

Ethics approval and consent to participate

Not applicable. This study is a systematic review of published literature and did not involve primary data collection from human participants.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analysed during this study are included in this published article and its supplementary information files. The full search strategy is provided in Additional File 1.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

SMM conceived the study, designed the review protocol, conducted the literature search, performed data extraction and quality assessment, synthesised the findings, and wrote the manuscript. The author read and approved the final manuscript.

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Figures

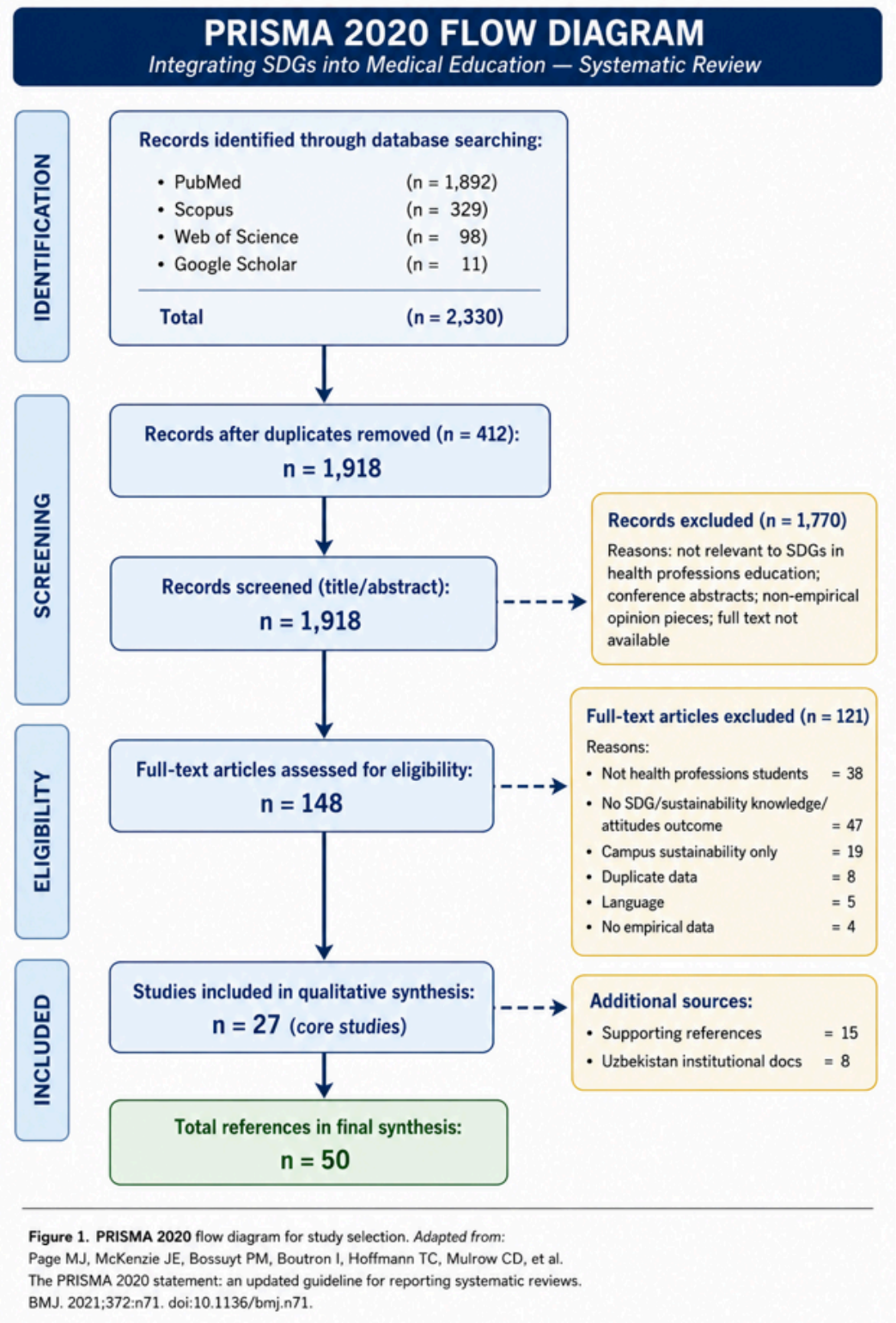


Figure 1. PRISMA 2020 flow diagram for study selection. *Adapted from:*
Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al.
The PRISMA 2020 statement: an updated guideline for reporting systematic reviews.
BMJ. 2021;372:n71. doi:10.1136/bmj.n71.

Figure 1

See image above for figure legend.