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RESEARCH

A systematic review of medical practitioners' retention and application of basic sciences to clinical practice

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Abstract

Background Medical education offers the foundational base for future healthcare professionals, with basic sciences playing a pivotal role in providing essential knowledge and skills for clinical practice. However, the long-term retention and application of this knowledge in clinical practice remain a significant challenge. This systematic review synthesised global evidence from diverse studies on the short / long-term retention and clinical application of basic sciences among medical doctors.

Methods A comprehensive search was conducted across six databases, including Web of Science, Scopus, Medline, CINAHL, Emcare, and Informit. The review included studies that encompassed a variety of study designs, participant groups, and educational interventions. The Quality Assessment with Diverse Studies (QuADS) tool was utilised to assess the quality of the reviewed studies.

Results A total of 10 studies were included in the review. The findings revealed that rehearsals significantly optimise the retention of basic science knowledge among medical practitioners. Retention varied by discipline, with medical practitioners retaining more knowledge in anatomy (mean scores ranging from 45.0 to 82.9%), while microbiology had the lowest retention score (39.1%). Factors influencing retention included age, gender, and curriculum type. Educational interventions such as targeted courses, integration of basic sciences with clinical skills, generative retrieval and continuous quality improvement in the curriculum were found to enhance both knowledge retention and clinical reasoning. The concept of 'encapsulated knowledge' demonstrates that integrated basic science knowledge helps in synthesising clinical presentations, reducing the need for detailed recall as clinical experience increases. The reviewed studies primarily involved interns and surgeons, leaving a significant gap in research for specialties like internal medicine and primary care/ general practice.

Conclusion Detailed retention of basic science knowledge may diminish over time; however, the conceptual framework remains essential for ongoing learning and clinical reasoning. This review's findings highlight the need for specialised educational interventions to improve long-term retention. Continuous professional development and targeted educational techniques are vital for maintaining clinical competence and applying basic science knowledge

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effectively throughout a medical career. Further research is needed to address gaps in specialty-specific knowledge application and the impact of different instructional methods.

Keywords Medical education, Basic sciences, Knowledge retention, Clinical reasoning, Postgraduate medical trainees, Medical practitioners

Background

Basic sciences are the foundation of modern medical practice and contribute substantially to medical education [1, 2]. Anatomy, physiology, biochemistry, microbiology, pathology, pharmacology and immunology underpin the understanding of normal structure and function, pathophysiology, diagnoses and treatment modalities [3–5]. A critical aspect of medical education is the cognitive integration of basic sciences into clinical reasoning and decision-making processes [6]. This establishes critical links between 'what' (possible diagnosis), to 'how' (disease mechanisms) and 'why' (underlying causes) [7, 8], improving diagnostic accuracy and an understanding of key clinical features [8]. The relevance of basic sciences, first highlighted in Flexner's 1910 report [9], remains relevant throughout medical careers, although new knowledge develops continuously in both the sciences and their clinical application [5, 8, 10–12]. However, maintaining current knowledge of basic sciences can be a significant challenge [1, 7, 10, 13].

Long-standing concerns exist regarding the retention of basic sciences knowledge among clinicians [5, 14, 15]. Retention after one year is reported to be approximately 67–75%, decreasing to about 50% after two years [16], even though basic science knowledge may be relied on when managing a challenging clinical problem [13, 17, 18]. A significant issue in monitoring retention is how this knowledge is assessed. Assessment often relies on multiple-choice questions (MCQs) [19], typically at the 'knows' (factual recall) and 'knows how' (knowledge application) levels [20, 21] at an early stage of integration with clinical reasoning. On the other hand, clinical assessment is usually at the 'shows how', 'does' and 'is' levels, relying on a combination of 'working knowledge' for commonly encountered clinical problems accessing and integrating longer-term stored knowledge when prompted by clinical presentations [22, 23].

Factors that may influence knowledge retention include curriculum approaches, frequency of testing, feedback delivery, and perceived clinical relevance [24]. There also appears to be differences based on gender and level of maturity that are not yet well understood [25]. Most of the literature on this topic relate to undergraduate medical training but the landscape changes in specialty training (residency and fellowship programs), perhaps due to the inherent diversity and complexity. Here the emphasis is on narrowing and deepening knowledge and skills to the relevant restricted clinical practice (including both supervised practice by interns and independent practice by residents and trained practitioners) [26, 27]. Continuing professional development (CPD) differs further, with the emphasis on maintaining currency, often involving new knowledge and skills, following a more self-directed learning approach [27]. It is likely that specialist clinical practice fosters the development of 'encapsulated knowledge', a form of transformed basic science knowledge that attaches relevant basic science knowledge to clinical scenarios and diagnoses [28, 29]. With increasing expertise, working memory may consist almost entirely of 'encapsulated knowledge' that is focused on the narrower scope of practice.

While clinicians continue to use basic sciences in clinical reasonings, their level of retention of basic science knowledge has not been as fully investigated as it is in the undergraduate medical training context [26]. For example, a recent review by Castillo et al. [30] identified interventions designed to aid the transfer of basic science knowledge to clinical reasoning in undergraduate health professions education. This highlights the need to understand the value of basic science knowledge retention in clinical reasoning within the dynamic context of postgraduate clinical practice [31].

This systematic review aimed to explore the long-term retention and application of basic sciences to clinical practice among medical practitioners. The insights gained may extend the existing body of knowledge and offer valuable strategies for enhancing value and impact of basic sciences in clinical practice. The review addressed the following research questions:

1. How relevant is the retention of basic sciences knowledge to clinical practice?
2. Does the study of basic sciences provide a framework for learning concepts that do not need to be retained?
3. What factors influence the retention, application and utility of basic sciences in clinical practice?

Methods

This systematic review adhered to the PRISMA (Preferred Reporting Items of Systematic Reviews and Meta-Analysis) guidelines [32].

Data sources and search strategy

Electronic databases were systematically searched from March 6th, 2023, to September 30th 2023, following the development of search terms. These databases included Web of Science, Scopus, Medline, CINAHL, Emcare, and Informit. Search strategies were designed using a mix of free text and subject headings specific to each database, to represent the concepts of medical education, basic science, clinical reasoning, and retention. Boolean operators "AND" and "OR" were used to refine the search strings to meet the unique requirements of each database. This approach aligns with best practice in systematic reviews, as it minimises bias and enhances the comprehensiveness of the search [33]. The complete search strategies employed in this review are detailed in the supplementary information section (Additional File 1). Additionally, hand searching of the reference lists of the studies included in the review was used to identify further relevant studies.

Inclusion and exclusion criteria

This systematic review sought primary, peer-reviewed articles published in English, from the year 2000 to 2023. The focus of this review was on medical practitioners' retention of basic sciences knowledge, its relevance to practice and factors associated with retention. Studies from other disciplines, such as nursing and allied health, were excluded. Also excluded were studies that considered only undergraduate medical students or participants' perceptions of the value of basic sciences in clinical practice. For more detailed information on the inclusion and exclusion criteria, please refer to Additional File 2.

Study selection

From all databases were uploaded into Rayyan (an online tool for systematic reviews that facilitates the screening and selection of relevant studies) [34]. The initial screening process included studies conducted in both undergraduate and postgraduate settings to ensure a comprehensive review of the available literature. This led to a larger pool of studies in the initial review process but ensured that all relevant studies, particularly those combining different educational levels, were thoroughly considered before application of exclusion criteria. The review was conducted independently by five authors (FAA, BSM-A, FOA, AS, and HM), who first went through each study's title and abstract and eliminated studies that did not meet the inclusion criteria. Following this, a full-text screening of the remaining studies was performed by the same authors. Only those studies that met the eligibility criteria were included in the final review. Any disagreements that arose during the screening process were addressed and resolved through consensus in weekly meetings with the entire project team.

Data extraction strategy

A standardised data extraction form was created using Microsoft Office Excel and data from the eligible articles were extracted by FAA and AS. The data extracted included the study title, authors, publication year, country, study aim/objectives, study design, setting, participants, and key findings in relation to knowledge retention, application and utility of basic sciences. Any discrepancies in data extraction were resolved through discussions involving all team members to achieve consensus. This rigorous approach ensured the accuracy and consistency of the data extraction process.

Quality appraisal

Quality appraisal is recommended in systematic reviews, particularly when they encompass diverse methodologies [35, 36]. In this review, two authors (FAA & AS) independently appraised all included studies using the Quality Assessment of Diverse Studies (QuADS) tool, developed by Harrison et al. [37], a modified version of the Quality Assessment Tool for Studies with Diverse Designs (QATSDD) [38]. This tool includes 13 criteria describing the quality of studies in systematic reviews. Any disagreements were resolved in a consensus meeting, ensuring a unified and comprehensive evaluation of all studies. Studies were not excluded based on their quality rating, though the significance of their findings were considered when reporting the results and drawing conclusions.

Results

Search results

A total of 4381 articles were identified in the initial search. After duplicates were removed, 3254 articles were eligible for title and abstract screening. We excluded 3129 articles that were deemed irrelevant to the topic, leaving 75 articles for full text screening. Seven of these articles met the inclusion criteria. An additional three studies were identified through hand-searching the references of the already identified studies. Therefore, a total of 10 studies were included in the systematic review. Details of the search strategy is presented in the PRISMA flow chart (Fig. 1).

Study characteristics

The studies included in this systematic review were published between 2002 and 2022 (Table 1). Many of the studies (80%, $n=8$) adopted quantitative study design such as cross-sectional, prospective, or randomized controlled trial (RCT) [39–46], with one study each employing multi-methods [47] and a qualitative approach [48] respectively. Of the 10 studies [39–48], four were conducted in Saudi Arabia [39, 40, 44, 46], two each in the Netherlands [42, 48] and USA [41, 45], and one each in Canada [47] and the UK [43]. Most of the studies (80%,

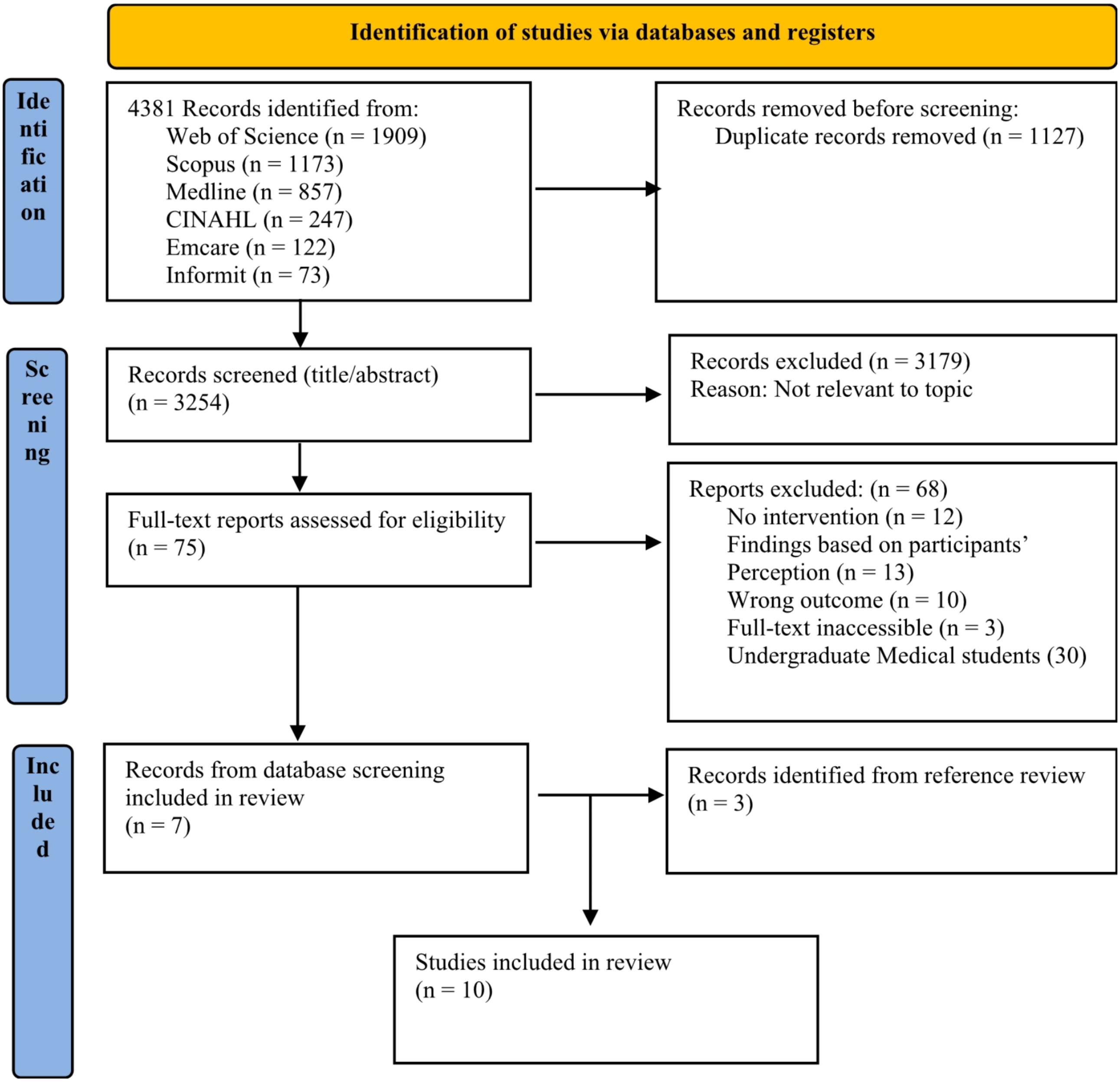

Fig. 1 PRISMA flow diagram [32]

n=8) [39–42, 45–48] were conducted in academic settings such as universities, while the remaining (20%, n=2) [43, 44] were conducted in clinical settings. The studies varied in terms of participant demographics, with the number of participants ranging from 10 to 300. Half of the studies (50%, n=5) involved a population of interns [39, 40, 44, 46, 48], three (30%, n=3) involved residents [41, 45, 47], and one each (10%, n=1) included senior doctors [42] and combined residents and interns [43]. The residents' specialisations included radiation oncology, anaesthesiology, and medical physics. In terms of curriculum, four (40%, n=4) of the studies employed a combination of traditional and problem based learning (PBL) curriculum [39, 40, 44, 46], while the rest (60%, n=6) did not specify the type of curriculum employed [41–43, 45, 47, 48]. Over half of the studies (60%, n=6) used assessment to examine the retention of basic science [39, 40, 42–44, 46]; one study considered the association between basic sciences and clinical reasoning [48], while the rest of the studies (40%, n=4) employed various forms of education or learning interventions [41, 45, 47, 48]. Anatomy was the most examined basic science subject (60%, n=6) in the included studies [41–43, 45, 47, 48], followed by biochemistry [42, 44] and physiology [39, 42] with two (20%, n=2) studies each, and one study (n=1) each for microbiology [40], pathology [42],

Table 1 Study characteristics and retention of basic science knowledge

Author, year of study and reference	Country & setting	Study design (e.g., RCT, cohort)	Participants (Specialisation): No.; Gender; Mean Age [years]	Basic science discipline & curriculum (e.g. Hybrid, Conventional, PBL)	Intervention or assessment strategy and outcome measured	Level of knowledge retention
AlMohanna et al. 2018 [39]	**Country**: Saudi Arabia **Setting**: Academic	Cross-sectional	**Interns**: $N=204$; Females (56.0%, $n=114$); Age: NA	**Basic science**: Physiology **Curriculum**: Conventional: (76.0%, $n=146$) Integrated (Hybrid PBL): (28.0%, $n=58$)	**Assessment**: Knowledge test **Outcome measured**: Knowledge retention	26.0% (52) passed the test (scores ≥ 60)
Alosaimi et al. 2022 [40]	**Country**: Saudi Arabia **Setting**: Academic & clinical	Cross-sectional	**Interns**: $N=300$; Females (55.0%, $n=164$); Age: 25.5 ± 1.02	**Basic science**: Microbiology **Curriculum**: Traditional: (36.4%, $n=107$) PBL: (63.6%, $n=184$)	**Assessment**: Examination using MCQs **Outcome measured**: Knowledge retention	*Mean score was 39.0% ± 18.0%. 18.3% (55) passed the exam
Chino et al. 2011 [41]	**Country**: USA **Setting**: Academic	Quasi-experimental: Educational intervention	**Residents (Radiation oncologists)**: $N=10$; Females: NA; Age; NA	**Basic science**: Anatomy **Curriculum**: Not stated. The modules included: 1-hour didactic introduction followed by a 1-hour session in the gross anatomy lab with cadavers prepared by trained anatomists.	**Intervention**: Structured education with MCQ examinations 1–3 months post intervention **Outcome measured**: Knowledge retention and perceived relevance	Median pretest score was 59.0% versus 86.0% post-test.
Custers & ten Cate 2011 [42]	**Country**: The Netherlands **Setting**: Clinical	Cross-sectional	**Doctors & Year 6 medical students**: $N=149$; Females: NA; Age; NA	**Basic science**: Anatomy, Physiology, Biochemistry & Pathology **Curriculum**: Not stated.	**Assessment**: Knowledge test (MCQs) **Outcome measured**: Knowledge retention	Doctors not long out of medical school achieved mean of 40.0% correct answers, and this declined with increasing years post-graduation. Doctors who attended medical school > 50 years ago achieved a mean of 25.0% correct answers
Gupta et al. 2008 [43]	**Country**: UK **Setting**: Clinical	Cross-sectional	**Interns & Registrars** Anatomy demonstrators, preregistration house officers (PRHOs), senior house officers (SHOs), and specialist registrars (SpRs). $N=128$; Females: NA; Age; NA	**Basic science**: Anatomy, **Curriculum**: Not stated.	**Assessment**: Knowledge test (MCQs) **Outcome measured**: Knowledge retention	PRHOs had a mean score of 72.1%, SHOs had a mean score of 77.1%, SpRs had a mean score of 82.4%, and 10 anatomy demonstrators had a mean score of 82.9%
Hamza et al. 2013 [44]	**Country**: Saudi Arabia **Setting**: Clinical	Cross-sectional	**Interns**: $N=200$; Females: (62.0%, $n=1124$); Age; NA	**Basic science**: Biochemistry **Curriculum**: Conventional: (70.5%, $n=170$) PBL or hybrid: (25.0%, $n=50$)	**Assessment**: Knowledge test (MCQs) **Outcome measured**: Knowledge retention	*The mean score of the participants was 45.3% ± 15.8%. 9.0% scored ≥ 7 while 61.5% scored ≥ 4–6 out of 10

Table 1 (continued)

Author, year of study and reference	Country & setting	Study design (e.g., RCT, cohort)	Participants (Specialisation): No.; Gender; Mean Age [years]	Basic science discipline & curriculum (e.g. Hybrid, Conventional, PBL)	Intervention or assessment strategy and outcome measured	Level of knowledge retention
Kleiman et al. 2017 [45]	**Country**: USA **Setting**: Academic	Randomised Control Trial (RCT)	**Residents** Anaesthesiology residents & medical students: *N* = 30; Females: (30.0%, *n* = 9); Age; NA	**Basic science**: Anatomy **Curriculum**: Not stated.	**Intervention**: Educational intervention (generative retrieval) and knowledge tested 1-week and 1-month post-intervention **Outcome measured**: Knowledge retention	Pre-intervention: The control group had a mean score of 50.0%, while the intervention group had a mean score of 49.0% 1-week post-intervention: The control group score was 82.0% versus 90.0% for the intervention group ($p=0.012$) 1-month post-intervention: The control group score was 72.0%, while the intervention was 83.0% ($p=0.026$)
Labranche et al. 2014 [47]	**Country**: Canada **Setting**: Academic	Mixed Methods Quasi experimental & Interviews -Educational intervention	Radiation oncologist (RO) residents, medical physics residents and RO fellow: *N* = 17; Females: NA; Age; NA	**Basic science**: Anatomy **Curriculum**: Not stated.	**Intervention**: Interactive learning and knowledge test (MCQs) **Outcome measured**: Knowledge retention and perceived value	Mean pre-test score for thorax session was 45.0% versus 85.0% post-test ($p=0.031$) Pre-test scores for the abdomen session was 60% versus 70.0% post-test ($p=0.008$) Pre-test scores for male pelvis session was 50.0% versus 80.0% post-test ($p<0.001$)
Mustafa et al. 2016 [46]	**Country**: Saudi Arabia **Setting**: Academic	Cross-sectional	**Interns & Final year medical students**: *N* = 161; Females: (24%, *n* = 39); Age; NA	**Basic science**: Pharmacology **Curriculum**: Conventional: (26.0%, *n* = 36) PBL or hybrid: (78.0%, *n* = 125)	**Assessment**: Knowledge test (MCQs) **Outcome measured**: Knowledge retention	*Mean score was 45.1% ± 19.7%. 19.3% (31) achieved a score of ≥ 7, while 47.8% achieved a score of ≥ 4 to 6
Vorstenbosch et al. 2016 [48]	**Country**: The Netherlands **Setting**: Academic	Qualitative (stimulated recall approach)	**Interns**: *N* = 10; Females: (70.0%, *n* = 7); Age; NA	**Basic science**: Anatomy **Curriculum**: Not stated. Course included: Lectures (± 5.0%) Self-study assignments (± 60.0%) Interactive lectures (± 10.0%) Computer-assisted learning (± 10.0%) Collaborative learning (± 10.0%) Practical/laboratory work (± 5.0%)	**Intervention**: Practice based learning **Outcome measured**: Clinical reasoning	NA

*Mean score converted to percentages

and pharmacology [46]. In terms of the outcome(s) measured, knowledge retention was the focus of most studies (70%, $n=7$) [39, 40, 42–46], followed by a combination of knowledge retention and perceived value in two studies (20%, $n=2$) [41, 47], and clinical reasoning in one study (10%, $n=1$) [48].

Knowledge retention and relevance of basic sciences

Nine studies [39–47] reported on knowledge retention of the basic sciences among medical practitioners (Table 1). Four of the studies [41, 43, 45, 47] focused on anatomy, while one study each focused on physiology [39], biochemistry [44], pharmacology [46], and microbiology [40]. In addition, one study [42] assessed four basic science disciplines (anatomy, biochemistry, physiology and pathology). Knowledge retention was assessed in these studies using tests or examinations. While all studies used known assessment tools, the measures used to report knowledge retention varied, including proportions of participants who passed and mean pass scores. Three of the four studies [41, 45, 47] used an intervention approach where the pre-test and post-test scores of participants were, respectively, 45–60% and 72–86%, 3 months later. The fourth study [43] investigated anatomy knowledge based on the number of years post-graduation from medical school. Newly qualified doctors and doctors who were two to four years postgraduation had average scores of 72.1% and 77.1%, respectively, while doctors in training with four or more years of experience and doctors who worked as anatomy demonstrators had higher scores of 82.4% and 82.9% respectively [43].

Knowledge retention in other basic science disciplines, including physiology, biochemistry, microbiology, and pharmacology, was assessed separately, and showed similar findings. Biochemistry and pharmacology showed similar retention scores with mean scores of 45.3 ± 15.8% [44] and 45.1±19.7% [46], respectively. Microbiology had the lowest mean score of 39.1 ± 18% [40]. Where all four disciplines (anatomy, biochemistry, physiology and pathology) were assessed, doctors who had recently graduated from medical school achieved an average score of 40%. The scores declined with increasing years post-graduation with doctors who graduated more than 50 years ago achieving a 25% correct score [42]. On the other hand, mean scores were not reported for physiology, rather 26% of the participants were reported to have passed the knowledge test [39].

Influence of basic science retention on clinical reasoning ability

Only one study [48] examined the influence of anatomy knowledge on clinical reasoning/decision making. Junior doctors were observed to apply anatomical knowledge, acquired from practice-based learning, throughout all phases of patient consultations, particularly during physical examination. The use of anatomical terms was closely linked to clinical reasoning, suggesting that doctors visualised the relevant anatomical information during their consultations [48]. Interestingly, about half of the doctors were not consciously aware of this visualisation process until the recall phase [48]. Some mental processes during the consultation excluded verbalisation as they were either partly unconscious, implicit, or overshadowed by new, reflective thoughts [48]. All participants reported visualising the necessary anatomical structures for the task during the consultation.

Factors influencing basic sciences knowledge retention

Five studies examined the influences on the retention of basic sciences [39, 40, 42, 44, 46]. Two of these studies [39, 40] identified predictors of knowledge retention, while the other three studies [42, 44, 46] identified associated factors. Predictors of knowledge retention were age, curriculum type, and retention interval (Table 2). Age and curriculum type were predictors of physiological knowledge recall [39]. Scores showed an inverse relationship with age, highlighting that younger doctors had

Table 2 Predictors and factors associated with knowledge retention among medical practitioners

Author, year of study and reference	Country	Study design (e.g., RCT, cohort)	Participants	Basic Science Discipline	Predictors and factors associated with knowledge retention
AlMohanna et al. 2018 [39]	Saudi Arabia	Cross-sectional study	**Interns**	Physiology	Younger Age (β = -0.20; $p < 0.01$) Type of curriculum (β = -0.23; $p < 0.001$)
Alosaimi et al. 2022 [40]	Saudi Arabia	Cross-sectional study	**Interns**	Microbiology	Participants from private colleges obtained higher scores (4.2 ± 1.8 vs. 3.8 ± 1.8; $P = 0.049$) compared to participants from Government colleges
Custers & ten Cate 2011 [42]	The Netherlands	Cross-sectional study	**Doctors ***	Anatomy, Biochemistry, Physiology and Pathology	Retention interval for doctors (β = −0.31; $p < 0.01$).
Hamza et al. 2013 [44]	Saudi Arabia	Cross-sectional study	**Interns**	Biochemistry	Graduates from schools with traditional curriculum had higher scores compared to graduates from schools with the integrated curriculum graduates = (4.71 ± 1.571 vs. 4.00 ± 1.571; $p = 0.006$)
Mustafa et al. 2016 [46]	Saudi Arabia	Cross-sectional study	**Interns**†	Pharmacology	Gender: Females had higher scores than males (5.38 ± 1.74 vs. 4.23 ± 1.97; $p = 0.001$) Preparation for exams: Participants preparing for exams had higher scores than those who were not (5.16 ± 2.06 vs. 4.31 ± 1.91; $p = 0.02$)

*Participants include year 5 and 6 medical students

†Participants include year 6 medical students

a better recall of knowledge compared to their older counterparts [39]. In addition, graduates from traditional or conventional schools performed better than those from integrated schools. Retention interval was inversely related to scores and predicted knowledge recall/ performance in four basic science disciplines (anatomy, physiology, biochemistry, and pharmacology). This implies that individuals who have been out of medical school for a longer time tend to have fewer correct answers compared to recent graduates. Three studies [40, 44, 46] reported on factors that influence knowledge retention, these include gender, preparation for examinations, type of curriculum and type of college. Females were reported to score higher than males, and individuals preparing for qualifying examinations scored higher than their counterparts [46]. In terms of curriculum, there were conflicting results. In some cases, participants from institutions with conventional educational approaches performed better than those trained based on hybrid or innovative educational methods such as problem-based learning (PBL) [39, 44]. Another study [40] indicated that interns who graduated from private colleges performed significantly better compared to those from government colleges.

Study quality

As shown in Table 3, the results of the QuADS assessment revealed variations in the quality assessment criteria of the reviewed studies. The articles scored between 22 and 36 out of a possible 39. The reviewed studies excelled in areas such as the articulation of research aims and objectives, providing a clear description of the research setting and target population, detailing the data collection process, the appropriateness of the analytical method used, and the relevance of the study design in achieving the research aims. However, the studies scored lower in areas like the theoretical or conceptual foundations of the research and the justification for the chosen analytical method. Notably, more than half of the studies (60%, $n=6$) [39–41, 43, 44, 46] scored zero for not considering research stakeholders in the research design or implementation. This highlights the need for improved engagement with participants and stakeholders in the co-design of research.

Discussion

This systematic review provides a comprehensive analysis of the long-term retention and clinical application of basic science knowledge among medical practitioners. It emphasises that retaining basic science knowledge is fundamental for accurate diagnosis and treatment planning. Basic sciences form the foundation for understanding complex clinical concepts and enhance overall clinical competence. Although natural knowledge decay occurs over time, effective educational interventions and continuous professional development significantly improve retention and application, helping practitioners handle diverse clinical challenges. These findings align with research suggesting that memory and cognitive abilities may decline with age, and instructional methods during medical education impact knowledge retention [16].

The review highlights the critical role of retaining basic science knowledge in developing clinical expertise. For example, detailed anatomical knowledge significantly affects diagnostic accuracy and treatment planning, particularly in specialties like radiation oncology [47]. A gap often exists between theoretical knowledge and practical application, necessitating tailored educational approaches. Senior professionals and clinical-year students may exhibit lower basic science knowledge due to insufficient rehearsal and traditional teaching methods that fail to integrate theory with clinical practice [49, 50]. Effective instructional interventions such as continuing education, dissection courses, generative retrieval, and integrated anatomy training enhance knowledge retention and application [42, 45, 47].

Factors like age, gender, and curriculum type (e.g., Problem-Based Learning) influence basic science retention, with younger practitioners typically retaining knowledge better [16, 51–53]. Doctors who graduated more than 50 years ago had lower scores in basic sciences, potentially due to restricted practice scope, fewer practice hours, changes in medical education, and natural cognitive decline [42]. Continuous professional development and targeted educational techniques are crucial for maintaining clinical competence and ensuring effective application of basic science knowledge throughout the medical career [54, 55]. Schmidt and Rikers [51] describe how basic science knowledge, through extensive clinical experience, integrates into higher-level clinical concepts or “illness scripts,” facilitating efficient case processing. Teaching basic sciences within a clinical context and introducing patient problems early in the curriculum are essential for developing ‘encapsulated knowledge’, highlighting the importance of integrating and retaining basic science knowledge [5].

While detailed retention of basic science knowledge may diminish over time, the conceptual framework remains crucial for ongoing learning and clinical reasoning [1, 2, 7, 10]. The concept of ‘encapsulated knowledge’ shows that integrated basic science knowledge aids in synthesising clinical presentations, reducing the need for detailed recall as clinical experience grows [49–51]. Research indicates that basic science knowledge improves diagnostic accuracy over time, with students who learned causal explanations for symptoms retaining diagnostic information better than those who learned epidemiological information [56]. This suggests that basic

Table 3 Quality assessment of the reviewed studies

S/N	QuADS criteria	Author & Year									
		AlMohanna et al. 2018 [39]	Alosaimi et al. 2022 [40]	Chino et al. 2011 [41]	Custers & ten Cate 2011 [42]	Gupta et al. 2008 [43]	Hamza et al. 2013 [44]	Kleiman et al. 2017 [45]	Labranche et al. 2014 [47]	Mus-tafa et al. 2016 [46]	Vorsten-bosch et al. 2016 [48]
1	Theoretical or conceptual underpinning to the research	1	1	1	1	1	1	1	3	1	3
2	Statement of research aims	3	3	3	3	2	3	3	3	3	3
3	Clear description of research setting and target population	3	3	2	3	3	3	3	3	3	3
4	The study design is appropriate to address the stated research aim/s	3	3	3	3	3	3	3	3	2	2
5	Appropriate sampling to address the research aim/s	1	1	2	1	1	1	3	3	1	1
6	Rationale for choice of data collection tool/s	0	0	1	2	0	1	1	1	3	2
7	The format and content of data collection tool is appropriate to address the stated research aim/s	3	3	3	3	2	2	3	3	2	2
8	Description of data collection procedure	2	1	3	3	3	2	3	3	3	3
9	Recruitment data provided	3	1	2	2	3	2	1	3	3	3
10	Justification for analytic method selected	2	1	1	1	1	1	3	3	1	2
11	The method of analysis was appropriate to answer the research aim/s	3	3	1	3	3	3	3	3	3	3
12	Evidence that the research stakeholders have been consid-ered in research design or conduct	0	0	0	1	0	0	3	3	0	1
13	Strength and limitation critically discussed	0	2	2	2	0	0	2	2	1	2
	Total Score (%)	24/39 (62%)	22/39 (56%)	24/39 (62%)	28/39 (72%)	22/39 (56%)	22/39 (56%)	32/39 (82%)	36/39 (92%)	26/39 (67%)	30/39 (77%)

0 = not at all; 1 = very slightly; 2 = moderately; 3 = complete.

science knowledge provides a coherent framework that enhances recall and organisation of clinical information, improving diagnostic skills.

Curriculum reforms integrating basic sciences with clinical training are vital for building a robust foundation for clinical practice [8]. This insight underlines the importance of basic sciences not just for their content but for structuring advanced clinical concepts, essential for developing competent clinicians [6]. A study showed that higher scores among anatomy demonstrators were likely due to repeated teaching exposure, while improved scores among doctors with more years post-graduation suggest the reinforcing effect of clinical practice [43]. Measuring clinicians' retention of basic science information, even if not directly relevant to current practice, has significant implications. Basic science knowledge often underpins critical thinking and clinical decision-making, and retention supports a broader understanding of patient care and treatment mechanisms. It becomes crucial in unexpected situations or complex cases requiring holistic understanding [2, 7]. Retaining basic science information, even if not directly relevant, maintains overall clinical competence and adaptability [14]. Frequent testing and relearning help clinicians stay prepared for various clinical challenges, enabling effective integration of new information and enhancing clinical skills over time. The concept of 'encapsulated knowledge' suggests that while detailed knowledge might not be explicitly retained, principles and frameworks from basic sciences are internalised and used in clinical reasoning [29, 51, 57]. Measuring retention helps identify gaps in understanding, guiding targeted educational interventions to reinforce critical concepts [58].

The observed differences between men and women [59, 60], graduates of private and government college education [40] and confusion over the impact of instructional methods [25], require further exploration. Notably, existing studies were conducted among interns, and surgeons with no study conducted in specialities like internal medicine, primary care or general practice. This is a significant gap in the literature, as medical practitioners irrespective of their area of specialisation often need to apply a broad range of basic science knowledge in their practice [59].

Strengths and limitations

The major strength of this review lies in its comprehensive analysis, drawing from a diverse range of studies with different designs, participant groups, and educational interventions. The use of the QuADS tool for quality assessment ensured a robust evaluation of included studies. Although the QuADS review indicated that the studies were generally of average quality, they collectively provide valuable insights into the long-term retention and application of basic sciences knowledge. These studies contribute to identifying key trends and gaps in current medical education practices, thereby guiding future research and educational plans. The inclusion of studies predominantly from Saudi Arabia, may introduce regional biases, affecting the generalisability of the findings. While this review provides valuable insights across different educational and healthcare contexts, cautious interpretation is necessary when applying the results to other regions. Other limitations include variability in the scope of medical programs, English language bias, and the predominance of cross-sectional studies, which may limit the generalisability of findings. Additionally, the relatively small number of studies on certain disciplines may constrain interpretation, although they highlight significant gaps in the literature.

Conclusion

This systematic review provides a comprehensive analysis of the long-term retention and clinical application of basic science knowledge among medical practitioners. The review underscores the critical importance of retaining basic science knowledge for effective clinical practice. Detailed knowledge is essential for clinical accuracy, while foundational concepts support clinical reasoning and new information synthesis. Effective educational interventions, including continuous education and generative retrieval, mitigate knowledge decay and ensure high standards of care. Integrating basic and clinical sciences is crucial for lifelong learning and clinical competence, ultimately enhancing patient outcomes. Tailored educational approaches and ongoing professional development are necessary to address knowledge gaps and maintain clinical excellence.

Abbreviations

GR	Generative Retrieval
LTR	Long-Term Retention
PBL	Problem Based Learning
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QuADS	The Quality Assessment with Diverse Studies
TEE	Transesophageal Echocardiography

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

All authors contributed to the conception and design of the study. FAA, AS and FOA were responsible for data collection, while BSM-A and FOA, provided advice on data analysis and interpretation. The initial drafts of the manuscript were developed by FAA and AS. All authors provided feedback on earlier versions of the manuscript and have read and agreed to the final version.

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Data availability
The dataset supporting the findings of this review is included within the article and its supplementary files.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The corresponding author (Bunmi S Malau-Aduli) is an Associate Editor with BMC Medical Education. All other authors have no competing interests.

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