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Dentistry Section

The Blueprinting in Microbiology for MBBS Students: A Scoping Review

GURJEET SINGH[1], RAKSHA SINGH[2], KOYALMANNAM RAMAN SETHURAMAN[3]

ABSTRACT

Assessment methods used in medical education serve as an impetus for teachers and students alike; in microbiology, however, traditional examination may sometimes be invalid in terms of content or of lacking uniformity. To explore blueprinting in undergraduate microbiology education and how it enhances the quality of assessment. A scoping review under Arksey and O'Malley's framework using databases from 2000 to 2024, including guidelines by the National Medical Commission (NMC) and peer-reviewed literature. The topics were fed into three categories: strategies of implementation, mapping to the cognitive domain, and influence upon learning outcomes. Blueprinting allows for a balanced representation of the content, enhanced promotion of higher-order thinking, and alignment of examination with the curriculum. Several institutions have reported greater student satisfaction and fairer-minded assessment processes since blueprints were adopted. The evolution of blueprinting has transformed assessment from farce, subjectivity, and manipulation to a structured, objective, and fair undertaking. Thus, the blueprinting ensures that the curriculum is in line with teaching and evaluation in microbiology and, in turn, follows the tenets of Competency-Based Medical Education (CBME)-The Principles. Although some implementation issues may arise, a systemic training of faculty and an unwavering support of the institution would establish blueprinting as a routine academic tool. Its widespread use would guarantee evaluation systems that are authentic, reliable, and learner-centred, which, in turn, nurture competent and confident practitioners.

Keywords: Assessment, Blueprinting, Cognitive levels, Competency-based curriculum, Medical education

INTRODUCTION

Assessment remains a core pillar of the entire edifice of medical education and thus dictates how students prepare for learning and how teachers design their teaching methodologies. This is especially important in subjects like microbiology, which provide a framework for understanding infectious diseases and principles of diagnosis and antimicrobial stewardship. The integrity, validity, and comprehensiveness of any form of assessment in microbiology thus become critical to ensure the production of competent future health professionals [1,2].

Traditionally, assessment patterns in undergraduate microbiology largely comprised essay-type questions, short-answer questions, and objective-type questions. These long-established formats are often accused of not being fully standardised, providing disproportionate weightage to different parts of the curriculum, and allowing the examiner's bias [2-6]. Several student feedback reports highlighted some of the issues, such as disproportionate emphasis on certain topics, omission of core concepts, ambiguous question phrasing, and excessive reliance on rote learning [2-6]. These inadequacies harm not just the fairness of assessment but also the credibility of curriculum delivery [1,2].

Blueprinting, as a concept and technique, has developed more language in recent times as a solution for the systemic infirmities [1]. It is a design approach to assessment that guarantees content coverage, the alignment of testing practices with learning outcomes, and an uninfluenced equal distribution of questions catering to different grades of cognitive level [1,2]. Any given question mapped against the curriculum content and the desired level of cognition (from Bloom's taxonomy classification), blueprinting, makes examinations more valid, transparent, and fair. It shifts the alignment from curriculum to examination and serves as a dependable standard to level student competence [1,7-12].

The very advent of Competency-Based Medical Education (CBME) by the National Medical Commission (NMC) further strengthens the demand for blueprinting [13]. CBME puts forth an outcome-based learning, defined competencies, and student-centric pedagogy. In this context, assessment should transcend any kind of summative tool and should work formatively to guide the learning process. Blueprinting systematically links assessment items to defined competencies, agreed performance levels, and allocated instructional time, thereby aligning assessment closely with the CBME framework [14-19].

With a syllabus that can be very broad and having such disciplines as general microbiology, immunology, bacteriology, virology, parasitology, mycology and applied clinical microbiology, blueprinting is considered a must. It makes sure that common diseases get due respect, while rare but critical conditions do get their due consideration. Also, it gives room for the assessment of higher-order cognitive functions, i.e., analysis, interpretation, and clinical application, which are sometimes missed in usual assessments.

This scoping review explores how blueprinting has been put into action in microbiology among Indian medical institutes; it weighs the potential challenges and gains, all culminating in a synthesis of best practices and suggestions. The review would essentially erect a wall against the gaps in current assessment procedures, thereby reflecting on the benefits of blueprinting as conceived and implemented. This would envision taking forward the entire microbiology education structure with regard to undergraduate medical students [13,20,21].

METHODOLOGY

A structured scoping review was undertaken to explore the scope and impact of blueprinting in microbiology education following the methodological framework laid down by Arksey H and O'Malley L [22]. This framework allows the exploration of the extent, range, and nature of research activity in a particular field and, therefore, is extremely suitable to investigate an educational innovation such as blueprinting. The intent was to perceive best practices, implementation strategies, outcomes reported for different studies, and gaps with respect to the existing literature and institutional practices.

The five stages of a scoping review were as follows [22]:

- Stage 1: Identifying the research question,
- Stage 2: Identifying relevant studies,
- Stage 3: Study selection,
- Stage 4: Charting the data,
- Stage 5: Collating, summarising, and reporting results.

Stage 1: Identifying the Research Question

Three core research questions steered this review:

How is blueprinting applied in undergraduate microbiology education?

What benefits and limitations have been implemented and reported by institutions and educators?

How well does blueprinting coexist with the CBME paradigm?

The questions are meant to represent both superficial and in-depth interrogations and cover not just the processes of blueprinting but also its products and how it has been adapted into the new competency-based curricula.

Stage 2: Identification of Relevant Studies

To find studies relevant to blueprinting in medical education, a research effort with an exhaustive strategy was undertaken. An electronic search in PubMed, Google Scholar, ScienceDirect, and ERIC systematically sought studies published between 2000 and 2024. Search terms included keywords strung together with Boolean operators, for example, "blueprint AND medical education," "blueprint AND microbiology," "competency-based assessment," and "undergraduate curriculum AND blueprint." Besides peer-reviewed journal articles, gray literature, which includes institutional guidelines, NMC policy documents, and unpublished faculty reports, was also reviewed to encompass the complete evidence spectrum. While the major thrust was on literature since 2000, key conceptual and theoretical references before 2000, such as Bloom's taxonomy and the basic principles of assessment theory, were purposely incorporated to give direction to theoretical adjudication and provide a historical background.

Although the primary search strategy covered the period 2000–2024, a limited number of seminal works published before 2000 (e.g., Bloom's taxonomy, classical assessment frameworks) were deliberately included. These foundational references were necessary to provide historical context, theoretical grounding, and conceptual clarity for the evolution of blueprinting in medical education.

Stage 3: Study Selection

Inclusion criteria were defined to ensure relevance and quality. Studies were included if they focussed on blueprinting in medical or health professions education, addressed undergraduate microbiology assessment, described CBME-aligned blueprinting strategies, or reported institutional experiences with blueprinting. Exclusion criteria comprised studies published in languages other than English, literature providing only anecdotal evidence without methodological rigor, and publications unrelated to microbiology or undergraduate medical education.

At the initial stages of the review, 212 records were found. After having duplicates removed (44), 168 records remained to be screened for titles and abstracts. 66 records were rejected at this stage for not meeting the inclusion criteria. Generally, these exclusions were for reasons such as studies that did not deal, in any way, with blueprinting or assessment in medical education; publications unrelated to microbiology or undergraduate training; and papers that talked about assessment strategies in general but did not refer directly to blueprinting. This left 102 full-text articles for detailed eligibility assessment.

During full-text review, an additional 18 articles were excluded. The reasons for exclusion at this stage included: lack of methodological clarity (n =7), purely anecdotal reports without systematic description of blueprinting (n =5), duplication of data already captured in another included article (n=3), and lack of relevance to undergraduate microbiology or CBME framework (n=3).

Finally, 84 articles and documents qualified for inclusion. These comprised peer-reviewed research articles, institutional reports, policy documents, and seminal theoretical works. All of these were subjected to data extraction and quality appraisal. Data extraction centred on characteristics of blueprinting models, cognitive assessment levels, curricular integration, tools for implementation, faculty training methods, student responses, and reported institutional outcomes.

The quality and relevance of the included sources were reviewed using a modified review checklist (adapted from the JBI Critical Appraisal Checklist for Systematic Reviews and Research Syntheses) for educational literature. In this way, only studies that met accepted standards of rigor and relevance were synthesised. The findings were thematically coded into blueprint design, curricular alignment, faculty development, student feedback, and institutional policy recommendations.

Stage 4: Charting the Data

Data were extracted from the included studies through a systematic approach using a structured proforma. Studies described various study properties-various blueprinting models, mapping to cognitive domains, strategies for integrating the curriculum, faculty development initiatives, student perceptions, and institutional-level outcomes. Aggregating data into broad categories would help for cross-study comparison and the finding of a common thread.

In this structured charting, the multiplicity of approaches and outcomes reported in the literature was synthesised into meaningful results.

Stage 5: Collating, Summarising, and Reporting Results

The papers then had their data extracted for collation and thematically analysed. Grouping was done into five domains: blueprint design and principles, curricular alignment and weightage models, faculty development and training challenges, student feedback and learning outcomes, as well as institutional case studies and policy recommendations. Thus, it would allow fleshing out different understandings of blueprinting in undergraduate microbiology education-Presumably, how it has been conceptualised, operationalised, and evaluated. Some standards of rigor and transparency were maintained by assigning a quality rating to included studies as well as a rating of relevance that came out of the usage of a modified appraisal checklist based on one originally developed from the JBI Critical Appraisal Checklist for Systematic Reviews and Research Syntheses. This is presented via narrative synthesis integrating evidence from empirical research, policy documents, and institutional experiences [23] [Annexure-1].

BACKGROUND AND RATIONALE

Microbiology equips prospective physicians with knowledge about pathogens, diagnostics, epidemiology, and antimicrobial stewardship. Given such importance, the assessment must be correlated to the actual learning outcomes and their clinical value. Contrary to this, institutions and studies have alleged that some basic flaws persist in that there is too much attention placed on trivial topics, scant attention is paid to core concepts, and alignment with learning objectives is totally lacking [2,23,24]. Blueprinting fixes the issue by making sure each question is mapped to a topic and a cognitive level so that it is comprehensive and fair-edged [1]. Besides making the evaluation transparent, blueprinting encourages teaching with a clear focus and finally leads to deeper student learning.

PRINCIPLES OF BLUEPRINTING

Blueprinting in educational assessment describes the systematic matching of curriculum content with evaluation methods to ensure comprehensive and fair assessment of students. In medical education, and particularly in microbiology, blueprinting works to resolve the presently recognised divide between the teaching and what is assessed. It improves the reliability, validity, and fairness of examinations by allowing proportional representation of all subject areas and cognitive levels. Put simply, blueprinting involves some key elements. First, the content listing involves listing in detail all syllabus topics. These are generally taken from the curriculum of the regulatory authority (for example, the NMC) and under broad categories like general microbiology, immunology, bacteriology, virology, parasitology, and mycology. Each topic is then further subdivided into themes, objectives, and competencies [18].

Learning objectives mapping consists of associating each content area with its learning objectives. This procedure considers the taxonomy of educational objectives (Bloom's taxonomy) relating to its different cognitive levels [25]. Mapping takes care of assessing recall at the lower levels and analysing and applying higher levels of thinking. So, perhaps a question on antibiotic resistance could be assessing student ability at the first level to recall mechanisms, second level to understand resistance patterns, and third level to apply this knowledge in clinical scenarios.

The significance of weighting is:

- **Weight allocation is a key step in blueprinting;** it ensures balanced and fair assessment design.
- **The Importance × Frequency (I × F) model is used,** where each topic is assigned a score based on its clinical relevance (importance) and the number of teaching or clinical exposures (frequency).
- **Clinically significant and frequently encountered topics receive higher weightage,** those topics that are assigned importance receive heavy weighting if they are more commonly encountered and only a light weighting if they are seen infrequently; thus, ensuring the assessment is aligned with real-world practice.
- Examples, tuberculosis and antimicrobial resistance get higher scores on importance and frequency, but that is not the case for rare diseases.

Cognitive domain distribution ensures representation of various levels of cognition in assessment. According to the revised Bloom's taxonomy, cognitive levels are usually grouped into:

- **Level 1: Knowledge and Recall** - Questions that require one to recall facts or definitions.
- **Level 2: Comprehension and Understanding** - Questions that ask for interpretation, classification, or summarisation.
- **Level 3: Application and Analysis** - Higher-order questions that induce a little deeper thinking and support the integration of knowledge, usually case-based or problem-solving.

Blueprinting will ensure that questions are evenly distributed along these cognitive domains to allow full assessment and avoid one-sided emphasis on rote learning.

That final version of the blueprint matrix or table shows the topics to be tested in the examination, the allotted marks, and the presumed cognitive level. This matrix can be utilised by examination setters or by faculty reviewers, even by students, to give some transparency and structure to the assessment design process [26,27].

Together, these principles provide strong support toward the development of valid, reliable, and student-centred assessments. They promote formative and summative evaluation goals and foster outcome-based education by aligning assessment practices very closely with course intent and learning goals [13,28].

IMPLEMENTATION OF THE MICROBIOLOGY CURRICULUM [18]

Based on the CBME framework of NMC, microbiology is divided into Paper I and Paper II as follows:

- Paper I: General Microbiology, Immunology, Cardiovascular and Blood Infections, Gastrointestinal and Hepatobiliary Infections, Musculoskeletal and Skin Infections [2,18].
- Paper II: Respiratory Tract Infections, Central Nervous System Infections, Genitourinary and STI Infections, Zoonotic and Miscellaneous Infections. Each section is further subdivided and rated according to importance and frequency. For instance, antimicrobial resistance and hospital-acquired infections are highly rated due to their extreme clinical significance and high frequency of occurrence in healthcare settings [2,18].

WEIGHTAGE CALCULATION AND COGNITIVE LEVEL DISTRIBUTION

In blueprinting, the formula for calculating weightage used is: Weightage = Importance (I) × Frequency (F). Scores generally go from 1 to 9. Suppose one chapter obtains an IF of 12 out of a total of 100; it then means that 12% of the marks would be given to that chapter. For example, weightage-wise, it applies as follows:

- General Microbiology: 28% weightage
- Immunology: 23% weightage
- CVS and blood infections: 21% weightage. The question papers contain different cognitive levels, such as:
- Level 1 (Recall): 30–40% of questions
- Level 2 (Understanding): 40–50%
- Level 3 (Application and analysis) shares from 20 – 30% of the whole [2,18];

Steps Involved in Blueprinting

1. Listing all content areas inside the syllabus of microbiology

As per the NMC guidelines, the contents of paper I and paper II are as follows:

Paper I- General Microbiology, Immunology, CVS and blood, GI and hepatobiliary, musculoskeletal, skin and soft tissue infections, AETCOM module 2.1.

Paper II- Respiratory tract infections, Central Nervous System (CNS) infections, genitourinary infections and STIs, zoonotic and miscellaneous, AETCOM module 2.8.

2. Pattern of the question papers

As per NMC guidelines, mark allotment for microbiology papers is 100 marks each for papers I and II.

Thus, each paper is of 100 marks.

3. Content validity

Weightage was calculated for content validity. Impact and frequency were used to calculate the desired weightage.

Impact refers to the clinical relevance of a topic. Scoring was as follows: minimal clinical significance = 1; moderate clinical significance = 2; marked clinical significance = 3.

Frequency refers to the prevalence of a disease or health problem. Scoring was as follows: low prevalence = 1; moderate prevalence = 2; high prevalence = 3.

4. Levels of cognition

Questions are categorised into various domains based on the revised Bloom's taxonomy action verbs used in the questions. Revised Bloom's hierarchy of cognitive learning is used for the assessment of the cognitive dimensions process. Level 1 comprised recognising and recalling; level 2 included understanding, interpretation, classifying, and comparing; and level 3 included application, analysis, and evaluation.

Blueprint for paper 1: There were a total of 29 competencies or outcomes in paper I. As per the CBME curriculum, the distribution of competencies for paper 1 totals 29, out of which 11 competencies are from General Microbiology and Immunology, seven from CVS & blood stream infections, eight from gastrointestinal and hepatobiliary system infections, and three from skin, soft tissue and musculoskeletal system infections. The outcomes were divided based on learning objectives by faculty members and allotted impact and frequencies to calculate cumulative weightage and marks. The blueprint of paper I show marks allotted for General Microbiology 28, Immunology 23, CVS and bloodstream infections 21, Gastrointestinal infections 10, Hepatobiliary system infections 5, and skin, soft tissue and musculoskeletal system infections 7 and AETCOM module. Distribution is not correct as the CVS and bloodstream infections, gastrointestinal and hepatobiliary system infections are a total of 15 competencies, but the distribution is less. Whenever the examiner prepares the question for summative or formative assessment, they should prepare the table first and allot the marks accordingly [Table/Fig-1,2].

Blueprint for paper 2: There were a total of 25 competencies or outcomes in paper I. As per the CBME curriculum distribution of competencies for paper 2 totals 25, out of which 3 competencies are from CNS infections, 3 from respiratory tract infections, 3 from genitourinary & sexually transmitted infections, and 16 from zoonotic diseases and miscellaneous. The outcomes were divided based on learning objectives by faculty members and allotted impact and frequencies to calculate cumulative weightage and marks. The blueprint of paper 2 shows marks allotted for respiratory tract infections as 54, and CNS infections, urogynaecological infections and AETCOM module 34 each. Distribution is not correct as the zoonotic diseases and miscellaneous are total of 16 competencies but the distribution is very less (only AETCOM). Whenever the examiner prepares the question for summative/formative assessment, he should prepare the table first and allot the marks accordingly [Table/Fig-3,4].

Topic/sub-topic	Importance (I)	Frequency (F)	IF of sub-topic	Weightage of the sub-topic within the topic	Weightage of the topic in the question paper	Marks allotted for each topic
1. General Microbiology,					29/100=0.29 × 100	28
(a) Introduction and history of microbiology, microscopy, morphology and physiology of bacteria, pathogenesis of bacterial infection, and bacterial genetics	4	3	12	0.12		12
(b) Overview of bacterial infections, general virology and overview of viral infections, general parasitology and overview of parasitic infections, and overview of fungal infections	2	2	2	0.02		2
(c) Epidemiology of infectious diseases, normal human microbiota, antimicrobial agents and resistance	2	1	2	0.02		2
(d) Healthcare-associated infections, sterilisation and disinfection	4	3	12	0.12		12
2. Immunology					20/100=0.20x100	23
(a) Immunity (innate and acquired), antigen, antibodies, antigen-antibodies reaction, complement	4	3	12	0.12		12
(b) Structure and function of immune system, immune responses, hypersensitivity	3	3	9	0.09		9
(c) Autoimmunity, immunodeficiency disorders, transplant and cancer immunology, immunoprophylaxis	2	1	2	0.02		2
3. Cardiovascular System (CVS) and Blood					21/100=0.21 x100	21
(a) CVS infection, blood stream infection, enteric fever, rickettsial infections	3	3	9	0.09		9
(b) Human Immunodeficiency Virus (HIV), viral haemorrhagic fever	2	2	4	0.04		4
(c) Malaria and Babesia Visceral Leishmaniasis and Trypanosomiasis	2	2	4	0.04		4
(d) Systemic candidiasis and systemic mycoses	2	2	4	0.04		4
4. Gastrointestinal (GI) infections					8/100=0.08x100	10
(a) Food poisoning, GI infections due to Enterobacteriaceae, cholera, Halophilic Vibrio and Aeromonas infections	3	2	6	0.06		6
(b) Viral Gastroenteritis	2	1	2	0.02		2
(c) Intestinal protozoan infections, intestinal helminthic infections	2	1	2	0.02		2
5. Hepatobiliary system infections					2/100=0.02x100	5
(a) Infective syndromes of hepatobiliary system	0	0	0	0		0
(b) Viruses causing Hepatitis	3	1	3	0.03		3
(c) Parasitic infections of hepatobiliary system	2	1	2	0.02		2
6. Musculoskeletal, skin and soft tissue infections					11/100=0.11x100	7
(a) Infective syndromes of Skin and Soft Tissue Infections (SSTI) and musculoskeletal system infections	1	1	1	0.01		1
(b) Staphylococcal infections, Beta haemolytic Streptococcal infections, gas gangrene, leprosy	2	2	4	0.04		4

(c) Fungal infections of skin, soft tissue and musculoskeletal system, viral exanthems and other cutaneous viral Infections, and parasitic infections of skin, soft tissue and musculoskeletal system	2	1	2	0.02		2
7. AETCOM module 2.1					4/100=0.04x100	6
AETCOM	3	2	6	0.06		6
TOTAL			100	1		100

[Table/Fig-1]: Calculation of topic wise weightage for topics in microbiology paper-1.

Topic	Weightage	LAQ (10 marks)	SAQ (5 marks)	MCQ (1 mark)	Marks allotted
1. General Microbiology (E)	0.28	1	3	3	28
2. Immunology (V)	0.23	1	2	3	23
3. CVS and blood stream infections (V)	0.21	1	2	1	21
4. Gastrointestinal infections (V)	0.1	0	2	0	10
5. Hepatobiliary system infections (D, V)	0.05	0	1	0	5
6. Skin, soft tissue and musculoskeletal system infections (V)	0.07	0	1	2	7
7. AETCOM module 2.1 (V)	0.06	0	1	1	6
	1	30	60	10	100

[Table/Fig-2]: Blueprint for paper-1 of the teaching learning module.
E: Essential; D: Desirable; V: Vital

Topic/subtopic	Importance (I)	Frequency (F)	IxF	Weightage of sub-topic to topic	Weightage of the topic in question paper	Marks allotted
1. Respiratory tract infections					54/100=0.54x100	54
(a) Infective syndromes of the respiratory tract, Streptococcus pyogenes, Diphtheria, Pneumococcus, Haemophilus influenzae, Mycoplasma pneumoniae, Chlamydia species and Legionellosis	5	5	25	0.25		25
(b) Tuberculosis and atypical mycobacteria Bordetella pertussis	4	4	16	0.16		16
(c) Influenza, parainfluenza, mumps and Respiratory Syncytial Virus (RSV), corona viruses and miscellaneous viral infections of respiratory tract	4	1	4	0.04		4
(d) Paragonimiasis, Tropical Pulmonary Eosinophilia (TPE), Pneumocytis pneumonia, Zygomycoses, Aspergillosis, Penicilliosis	3	3	9	0.09		9
2. CNS infections					34/100=0.34x100	34
(a) Infective syndromes of CNS, bacterial meningitis, tetanus	5	5	25	0.25		25
(b) Viral meningitis and myelitis, viral encephalitis and encephalopathy	3	2	6	0.06		6
(c) Parasitic and fungal infections of CNS	3	1	3	0.03		3
3. Urogynaecological					6/100=0.06x100	6
Infective syndromes of urinary tract	2	1	2	0.02		2
Infective syndromes of genital tract	2	2	4	0.04		4
4. AETCOM module 2.8					6/100=0.06x100	6
AETCOM	3	2	6	0.06		6
Total			100	1		100

[Table/Fig-3]: Calculation of topic wise weightage for topics in microbiology paper-2.

Topics	Weightage	LAQ	SAQ	MCQ	Marks allotted
Respiratory tract infections (V)	0.54	2	6	4	54
CNS infections (V)	0.34	2	2	4	34
Urogynaecological (V)	0.06	0	1	1	6
AETCOM module 2.8 (V)	0.06	0	1	1	6
	1	40	50	10	100

[Table/Fig-4]: Blueprint for paper 2 of the teaching-learning module.

FACULTY TRAINING AND CHALLENGES

Training Methods for Faculty in Blueprinting Definition: Training methods for faculty in blueprinting are structured approaches such as workshops, Faculty Development Programmes (FDPs), peer-mentorship, and digital tool training designed to equip medical educators with the skills to align teaching, learning, and assessment. These processes are geared toward imparting expertise in the application of structured frameworks (such as the Bloom Taxonomy), blueprint matrices, and applying educational technologies to complement assessment validity and transparency.

Evidence in Literature: Workshops and FDPs: These workshops for faculty development have been effective in increasing the knowledge and skills of teachers on matters involving blueprinting and design of assessments and of aligning curricula. Studies show that even short modular workshops can produce measurable improvements in faculty confidence and application of blueprinting principles [28,29].

Peer Learning and Mentorship: Mentorship and collaborative training—where experienced educators guide juniors—enhance adoption of blueprinting by reducing resistance and providing contextual learning [30,31].

Use of Digital Tools: Training faculty using blueprinting software and spreadsheet-based templates reduces time burden and increases precision. Evidence suggests that technology-supported training can lead to wider adoption of blueprinting in resource-limited settings [32].

Certification and Modular Courses: A formal training in the procedure of forming, conducting, or assessing medical education fellowships or certificate courses delivers structured exposure to assessment principles, including blueprinting, to sustain faculty practice [33,34].

Despite the advantages proposed for microbiological blueprinting, at present, implementation in ordinary medical education is crestfallen owing to a slew of challenges. They include scant exposure for faculty, time limitation, technology unfamiliarity, and resistance to the upending of the status quo in assessment patterns. One major barrier is the lack of formal training among faculty in blueprinting techniques. Many medical educators have not been oriented to tools that align curriculum with assessments using a structured cognitive framework such as Bloom's taxonomy [2,27,34].

Mostly because of apprehension about time and effort spent on developing and maintaining a blueprint, there is resistance to blueprinting for departments that already have heavy clinical and teaching commitments. Some faculty members, mainly those trained with older pedagogies, might just view these activities involved in blueprinting as time-consuming and rigid without realising the long-term benefits of blueprinting [18,34].

Another hurdle stems from the technological and methodological limitations many institutions possess. To establish a detailed and accurate blueprint, it requires not only a thorough knowledge of the subject matter and curriculum but also elementary know-how of working with spreadsheet software or blueprinting applications. The absence of these tools in an institution or the digital incompetence of the faculty makes for a very steep uphill task [35].

Several measures have been recommended and implemented by progressive institutions in attempting to overcome these challenges; of these, the most effective is the conduct of regular FDPs and workshops [35,36]. The said programmes help in a more complete introduction to the rationale behind blueprinting, its procedure, and the advantages, enabling them to apply those principles themselves in real classroom and examination situations. Short modular courses and certifications in medical education have also contributed to faculty development [36,37].

Additionally, creating and distributing easy-to-use templates and digital tools for blueprinting could significantly minimise the time demand on faculty and improve precision in the process. KLE University has shown the effectiveness of setting up joint blueprinting committees consisting of members across multiple departments. These committees not only guide the development of expertise but also standardise blueprinting procedures and foster quality assurance [13,37].

The next road forward is to institutionalise blueprinting as a mandatory academic exercise supported by the medical college examination cell or curriculum committee. Such a top-down policy-driven order ensures that the faculty will accept ownership of the process and will regard it as a routine aspect of assessment design rather than an optional activity [38-40].

Peer-learning and mentorship mechanisms are also helpful in inculcating blueprinting practices. Experienced faculty members can walk junior colleagues through the process, building clarity and expanding adoption. And, lastly, establishing feedback loops through which faculty members witness better student results and receive their own set of external feedback is going to reaffirm and hence increase their appreciation for blueprinting and its sustainability [40-43].

While faculty training and systemic support are essential, fostering a culture of academic openness and innovation is equally critical for the successful and sustained adoption of blueprinting in microbiology assessment [23,33]. Despite its benefits, blueprinting is not widely adopted due to several challenges:

- Lack of faculty awareness and training
- Resistance to change from traditional methods
- Time and resource constraints [27,33]. Effective implementation strategies include:
- Faculty development workshops
- Use of blueprinting software and digital tools [1]
- Forming departmental blueprinting committees
- Including blueprinting training in medical education fellowships

STUDENT FEEDBACK AND LEARNING OUTCOMES

Student feedback is a crucial measure of the effectiveness and acceptability of any educational intervention. In the context of blueprinting, students have consistently reported significant improvements in their learning experiences, assessment clarity, and perceived fairness of exams. Post-implementation studies across institutions such as KLE University and AFMC Pune have recorded overwhelmingly positive responses from the student body [2,38].

One of the most frequently cited benefits is the enhanced alignment between classroom teaching and examination content. Students noted that the exams more accurately reflected the instructional focus, reducing the disconnect often experienced with traditional assessments. This alignment provided them with clearer expectations, allowing for more targeted and efficient preparation strategies [13,19].

Furthermore, blueprinting introduced students to a broader spectrum of cognitive domains. Many students appreciated the inclusion of case-based and problem-solving questions, which required the application of knowledge rather than rote memorisation. This shift in question type helped students develop critical thinking skills and better prepare for clinical reasoning tasks expected in later stages of medical training [36,44-48].

Coderre S et al., reported that a well-constructed blueprint is a valuable tool for medical educators. In addition to validating evaluation content, a blueprint can also be used to guide the selection of curricular content and learning experiences. It encouraged more problem-solving and application-based questions, leading to improved student satisfaction and performance in knowledge application tasks [26].

Kaur M et al., reported that blueprinting physiology curriculum improves validity, reliability and acceptability of both formative and summative assessments and thus establishes a balance between teaching and students' overall learning. Blueprinting the medical curriculum can be very helpful in actual execution of the CBME programme as implemented by the MCI. Also, students exposed to blueprint-based examinations demonstrated better coverage of syllabus content and engaged with higher-order cognitive domains, especially analysis and synthesis [19].

Patil SY et al., (2015), reported that the students and faculty felt that there was appropriate distribution of questions across topics (77% and 89%, respectively), appropriate weightage given to topics of public health importance (65% and 100%), examinations were fair (86% and 89%). All the faculty felt that blueprints align assessment with objectives and help as a guide and for paper construction. Students were satisfied as blueprinting helped them to attempt the examination better. The faculty who validated the blueprint felt that it helps in the distribution of appropriate weightage and questions across the topics and blueprinting should be an integral part of assessment. Blueprint-driven assessments reduced student complaints of bias, increased perceptions of fairness and transparency, and encouraged preparation across all topics [1].

Ismail MA-A et al., reported that a well-constructed blueprint is essential and important to ensure the validity of any assessment content is aligned with the intended learning outcomes and learning experience. Inclusion of case-based items through blueprinting improved critical thinking and clinical reasoning skills among undergraduate medical students [49].

Tabish SA (2008), mentioned that the test of clinical competence, which allows decisions to be made about medical qualification and fitness to practice, must be designed with respect to key issues including blueprinting, validity, reliability, and standard setting, as well as clarity about their formative or summative function. Highlighted that aligning assessment with learning outcomes via blueprinting directly improves validity and reliability of exams while enhancing learner engagement [50].

Formative assessments guided by blueprints also proved to be invaluable learning tools. These assessments enabled students to self-assess their performance against clear objectives, recognise their strengths and areas for improvement, and seek timely academic support. Feedback loops fostered a sense of ownership and responsibility toward learning, which is one of the key principles of Competency-Based Medical Education (CBME) [18].

Students also expressed reduced examination-related anxiety, attributing it to the predictability and transparency brought by the blueprint. Knowing that each topic would be fairly represented and that questions would be distributed across various cognitive levels offered a sense of academic equity. This perception of fairness increased their motivation and trust in the educational system [51-55].

Quantitative surveys further supported these qualitative insights. In one reported case, over 85% of students agreed or strongly agreed that blueprint-aligned exams were more relevant and helpful in guiding their learning [1]. Similarly, satisfaction scores on the structure and content of exams rose markedly after the introduction of blueprinting protocols [2].

However, some students initially expressed concerns about

- The issue of complexity with respect to higher-order questions in general and those based on analysis, synthesis, and application in particular.
- Unfamiliar with new types of questions in case-based scenarios or problem-solving-based format-contrary to recall questions.
- Bigger cognitive demands: because preparation involves the wider cognitive domain, preparation takes more time and effort.
- Fear of inferior performance: Fear of performing poorly simply because of having much less exposure.
- Adjustment period: Struggling with the shift from rote memorisation toward critical thinking and reasoning tasks.

This concern was addressed by incorporating regular formative assessments, feedback mechanisms, and exposure to a variety of question types during the teaching-learning process [56-59].

In summary, the integration of blueprinting into microbiology assessments has received strong endorsement from students across different medical institutions. It has helped foster a learner-centered environment where assessments reinforce learning, promote critical thinking, and support academic success. These outcomes further validate the role of blueprinting as not just an assessment tool but a pivotal component of the educational process [13,19,24]. Students consistently reported positive perceptions post-blueprinting implementation:

- Felt assessments were more representative of the taught material
- Reported greater clarity in expectations
- Found study preparation more focused and effective [13,19]. Furthermore, formative assessments aligned with blueprints helped students identify weak areas early and prompted self-directed learning [24].

CASE STUDIES AND EMPIRICAL EVIDENCE

Numerous empirical investigations and institutional-level case studies attest to the paradigm's success in improving the quality and fairness of assessments within medical microbiology. These case studies serve as guides for implementation and as an eye-opener into the real-world benefits and problems faced by educational institutions.

A retrospective analysis at the Armed Forces Medical College (AFMC), Pune, scrutinised summative theory question papers for microbiology for five academic years, revealing non-uniform coverage of important microbiology topics and an assessment procedure lacking in cognitive diversity. Hence, post-introduction of blueprinting, there was a measurable improvement in content validity and a reduction in the number of ambiguous or repetitive questions that were being asked. Also, the feedback from faculty pointed to increased confidence in examination settings and better performance of students in terms of learning outcomes that were aligned accordingly [2].

A relevant example is from KLE University, Karnataka, which drew blueprinting into curriculum reform in line with CBME. The introduction of the blueprinting framework was carried out in tandem with sensitisation workshops for faculty and digital blueprinting tools. This resulted in a remarkable improvement in both formative and summative assessments, while the faculty felt that these were the least biased in the construction of question papers, and in turn, students felt that they were also a lot clearer about what to expect in the examination and how to prepare for it [1,19].

The findings of Kaur M et al., in physiology education, offer some insightful transferable lessons for blueprinting. While not confined to microbiology, their results highlight the generic advantages of blueprinting in preparing assessments balanced in content coverage and aligned with teaching time and emphasis [19].

Taken together with the backing of these institutions, it becomes clear that blueprinting aids in making assessments more objective and fairer, while at the same time improving the quality of teaching, student satisfaction, and faculty development. The case studies highlight the flexibility of blueprinting models in adjusting to institutional conditions, thus reinforcing their soundness across varying medical colleges with differing infrastructural and academic profiles.

This empirical need and case-based support provide a strong thrust towards the need for advocating widespread usage of blueprinting in medical microbiology education, amenable to both learning objectives and regulatory standards [1,2,13,19]. Blueprinting benefits have also been reported from multiple institutions. Some of the examples are:

- AFMC Pune: Found that the blueprinting improved the validity of content and degree of student satisfaction [2].
- KLE University: Found blueprints helped in promoting fairness and increased confidence among the faculty in the assessment process [1]. Blueprinting in all cases ensured the balancing of content coverage with the degree of cognitive engagement [13,19].

INTEGRATION WITH COMPETENCY-BASED MEDICAL EDUCATION (CBME)

This landmark revision of undergraduate medical training was brought about by the NMC with the introduction of CBME in India. Traditional curricula that recognised time spent and factual abilities as milestones for progression have now been replaced by CBME, which clearly defines competencies and embraces student-centred learning with real-world, clinical-task-relevant outcomes [18,58].

Blueprinting in this context is one of the most important elements in instructional design and assessment methods. It allows educators to directly map the items of assessment to the specific learning outcomes or competencies intended. This ensures that assessment is not a pure summative point but a formative checkpoint corresponding to the developmental milestones of the medical student. Items on a blueprint can be cross-referenced to the national competency framework to ensure compliance with CBME requirements [31,37,58].

All aspects and core pillars of CBME knowledge, skills, attitudes, communication, ethics, and professionalism require complex, layered methodologies of assessment. Blueprinting facilitates such integration by ensuring that the assessment itself is representative of each domain. For instance, while the assessments may not directly encompass microbiological concepts, a well-designed blueprint could also include case scenarios that test diagnostic reasoning, patient communication, and ethical issues, e.g., antibiotic stewardship [58,60-65].

Blueprinting is a complement to the longitudinal assessment system stressed in the CBME. As students progress through the various stages of the MBBS programme, their growth in specific competencies can be tracked through repeated examinations based on blueprints. This continuous monitoring favours adaptation of learning strategies and proscribes remedial measures whenever deemed necessary, further endorsing the development of a personalised learning track [1,12,61].

Also, blueprinting may equally allocate time for various requisite topics and take away unnecessary repetition from the content. CBME requires teaching-learning processes to be graded with community health needs and burden of disease. Blueprinting can be weighted by epidemiological data, public health priorities, and local healthcare demand to ensure relevance and contextual wholeness in the assessment of the student [2].

Some institutions have started incorporating blueprinting into their CBME-aligned curricula. Faculty members at these institutions report that they have greater clarity in setting learning goals and find it easier to align formative assessments with teaching sessions and that this is benefiting student understanding of what is expected of them. The students, in turn, feel empowered by knowing what they are being evaluated on and why, which is consistent with CBME's notion of shared accountability in the learning process [13,18].

In addition, blueprinting also facilitates the paradigm shift from single-teacher examination construction to team, interdisciplinary examination planning, allowing for collaboration among microbiology educators and other clinical disciplines to ensure the holistic development of students in both vertical and horizontal competencies [66-70]. In brief, blueprinting serves as the structural and philosophical link bridging the classical systems of assessment with the newer framework of CBME. It allows for the transformation of assessment from a compartmentalised chore into a vibrant educational activity that perpetuates growth, achievement of competency, and improved healthcare delivery outcomes [1,13,18]. Blueprinting is a vital process in a CBME model. It enables:

- Alignment of assessment with competencies desired for development [18].
- Providing integration among knowledge, skills, and attitude domains
- Providing a framework for outcome-based learning and continuous feedback
- Providing equal weightage for all systems and diseases. It supports longitudinal assessment formats encouraging mastery rather than superficial performance [1,13].

RECOMMENDATIONS

- Based upon empirical evidence, institutional experience, and best practice, the following are some strategic recommendations for increasing the effectiveness of blueprinting in microbiology education:

Institutional Policy and Integration

- Set blueprinting as a criterion for summative and internal assessment. Continue formulating policies related to assessment blueprinting and curricular frameworks at the level of the institution's policies and scope of assessment practices.
- Anchor institution's goals to national benchmarks such as the provided NMC standards.

Faculty Training and Capacity Development

- Conduct periodic FDPs that aim at improving participants' assessment literacy and blueprinting skills.
- Construct workshops that display real course materials to illustrate the process of developing blueprints.
- Foster sponsored peer mentoring and championing by designating department leaders in blueprinting.

Technological Support and Tools

- Create or adopt uniform digital templates and software that aid users in building blueprints.
- Employ LMS or Excel-based matrices to incorporate taught content with assessable items.
- Maintain technical support for faculty in designing and revising blueprints

Interdisciplinary and Collaborative Approaches

- Facilitate active participation between clinical and basic science arms of the clinical to encourage jointly devised integrated assessments.
- Construct inter-faculty blue-printing working groups to promote cross-disciplinary holistic evaluative approaches in diagnosis and treatment of multi-disciplinary subjects.
- Achieve curriculum vertical and horizontal alignment through the use of blueprinting.

Student Involvement and Transparency:

- Share general outlines or topic-weighted matrices with students to enhance transparency.
- Use blueprint-aligned formative assessments as learning tools and to set expectations.
- Gather regular feedback from students to refine the blueprinting process [13,19].

Quality Assurance and Review Mechanism

- Conduct regular audits comparing actual examination content with the blueprint.
- Maintain archives of previous blueprints and question papers to assess progress and consistency.
- Use student performance data to evaluate and refine the blueprint over time [2,71-77].

National and Regional Collaboration

- Encourage sharing of blueprinting practices and models through academic conferences and medical education networks.
- Collaborate with regional medical universities to create centralised blueprinting guidelines tailored to local health needs [78-81].
- Implementing these recommendations can help medical institutions create robust, reliable, and learner-centred

assessment systems in microbiology. Blueprinting, when embedded as an institutional norm rather than an occasional tool, enhances both assessment quality and the overall educational experience. To maximise the effectiveness of blueprinting in microbiology:

Policy integration: Make blueprinting mandatory for all summative assessments [18,82]

Training modules: Include blueprinting in faculty development programs [31,83]

Automated tools: Use Excel or specialised software to create and manage blueprints [19]

Interdisciplinary collaboration: Involve clinicians to ensure practical relevance

Quality assurance: Periodic review and audit of question papers against blueprints [84]

Student involvement: Share blueprints or outlines with students to guide preparation [12,13]

CONCLUSION

In blueprinting, validity, reliability, and procedural fairness in the examinations in medical education have all been improved. For an effective implementation, there must be training for the faculty, and strong institutional support should be available. Because assessment drives teaching and learning, blueprinting test evaluation with learning objectives. To ensure fair coverage of curricular content. This scoping review delves into conceptualising, practicing, the benefits, and impediments of blueprinting in undergraduate microbiology. By reviewing literature, policy, and curriculum innovations, we outline the processes of content mapping, weight allocation, and Bloom's taxonomy for test blueprinting. Evidence shows that blueprinting leads to assessing better, ensuring transparency and alignment between teaching and learning outcomes, while gaps still remain in faculty training and institutional adoption.

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PARTICULARS OF CONTRIBUTORS:
1. MHPE Scholar, Institute of Health Professions Education, Sri Balaji Vidyapeeth (Deemed to be University), Pillaiyarkuppam, Pondicherry, India; Professor, Department of Microbiology, Abhishek I Mishra Memorial Medical College and Research, Durg, Chhattisgarh, India.
2. Professor, Department of Microbiology, Abhishek I Mishra Memorial Medical College and Research, Durg, Chhattisgarh, India.
3. Endowed Chair and Emeritus Professor, Department of Health Professions Education, Institute of Health Professions Education, Sri Balaji Vidyapeeth (Deemed to be University), Pillaiyarkuppam, Pondicherry, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Gurjeet Singh,
Institute of Health Professions Education, Sri Balaji Vidyapeeth (Deemed to be University), Pillaiyarkuppam, Pondicherry-607402, India.
E-mail: gurjeetsingh360@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jun 14, 2025
- Manual Googling: Sep 27, 2025
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AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was informed consent obtained from the subjects involved in the study? No
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