Original Article

Constructing a Cognitive Map of Subject Domains in Community Medicine for Undergraduate Students: A Qualitative Study

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ABSTRACT

Background: The National Medical Commission (NMC) 2024 competency-based guidelines feature an extensive framework in Community Medicine. Navigating this vast curriculum imposes a massive cognitive load on undergraduate learners. This study aimed to map out student-perceived curriculum bottlenecks and explore the underlying reasons and respective remedial solutions. **Methods:** An institution-based qualitative study utilizing cultural domain analysis was conducted in May 2026 among 30 stratified purposively sampled Phase III MBBS students in West Bengal. Participants completed two independent tasks: a constrained ranking exercise of 20 NMC-mandated subject domains and an unconstrained pile sorting task. Data were analysed using multidimensional scaling (MDS), hierarchical cluster analysis (HCA), and manual thematic analysis. **Results:** Constrained ranking revealed "Biostatistics and its Applications" as the apex extreme bottleneck (Perceived Difficulty Score: 13.03). HCA and MDS partitioned the domains into four distinct thematic clusters. Cluster A (Core Epidemiology; Score: 12.00) carried analytical barriers and a high cognitive load. Cluster C (Health Administration; Score: 10.26) lacked clinical correlation, requiring problem-based learning. Cluster D (Family Health; Score: 9.50) suffered from an overly theoretical nature, making field visits and peer-mentoring necessary remedies. Conversely, Cluster B (Environmental Health; Score: 7.69) carried the lowest cognitive load, emerging as an ideal candidate for self-directed learning (SDL). **Conclusion:** Undergraduate medical students experience structural variations in curricular difficulty. These data-driven insights enable faculty to deploy targeted pedagogical interventions and optimize limited institutional resources.

Keywords: Cognitive Barrier, Curriculum, Medical Undergraduates, Public Health Education, Qualitative Research

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INTRODUCTION

The National Medical Commission (NMC) in 2024 updated its guidelines for Competency-Based Medical Education (CBME), outlining a rigorous and extensive framework of specific competencies that undergraduate medical students must attain.[1] Within the discipline of Community Medicine alone, this framework enlists an exhaustive array of 136 distinct competencies distributed across 20 major subject domains.[1,2] Navigating this vast curriculum presents a significant cognitive load for learners, who frequently perceive varying degrees of difficulty across different thematic areas.[3] This variation in student perception creates a distinct pedagogical challenge for medical educators and facilitators, who must decide how to optimally allocate instructional time, resources, and remedial attention.

Compounding this challenge is the fact that student difficulties are highly individualized, yet resource and logistical constraints make personalized, one-on-one remediation impractical in large institutional settings.[4] Furthermore, ad-hoc or subjective adjustments to teaching focus risk introducing pedagogical bias, potentially neglecting core curricular areas. Traditional student feedback mechanisms often fail to capture how students structurally relate these diverse topics to one another.

To bridge this gap, it is essential to look beyond individual feedback and identify a collective, structured consensus.[5,6] Utilizing cultural domain analysis techniques, which allows researchers to systematically capture student perceptions and these subjective experiences can be translated into an objective, generalized cognitive map.[7,8] While student perceptions are inherently subjective, Cultural Domain Analysis grounded in Cultural Consensus Theory applies formal statistical algorithms to quantify shared cognitive structures, thereby translating individual subjective inputs into an objective, data-driven map. Constructing such a cognitive map for Phase III MBBS students will provide faculty with a data-driven blueprint of perceived curriculum bottlenecks. This will ultimately enable institutions to design targeted, structurally sound remedial interventions and optimize resource allocation without compromising curricular equity. This study was designed as an exploratory, cross-sectional qualitative study to systematically evaluate these cognitive bottlenecks. Thus, our study aimed to explore the degree of perceived difficulty of subject domains in community medicine as per CBME 2024 among phase III MBBS professional students in a medical college of West Bengal. Subsequently, we also tried to elicit the underlying reasons behind those perceived difficulties and respective remedial actions among them.

MATERIAL AND METHOD

Study type & study setting: This institution-based exploratory cross-sectional qualitative study was conducted among 30 phase III MBBS students of Sarat Chandra Chattopadhyay Govt. Medical College and Hospital, Uluberia, in May 2026, because a sample size of 30 was deemed to be sufficient to meet the saturation and consensus requirements for qualitative cultural consensus theory.[6,7] In Cultural Domain Analysis, a sample size of 20 to 30 respondents is mathematically demonstrated to achieve high statistical confidence (power > 0.95) for identifying cultural consensus within a homogenous group. All the 99 students of phase III MBBS who had a minimum 60% attendance in theory and practical classes were eligible for the study. Minimum 60% attendance along with remedial classes was the minimum threshold to appear for the summative examination. It was chosen purposefully as a quality assurance measure. It was done to ensure that participants had a baseline familiarity with the subject domains. Because a response from a student with less attendance might be spurious in identifying the curricular bottleneck. The eligible students were further classified in strata, based on marks obtained in the last internal assessment of community medicine, such as, i.e., below 50%, 50 to 60%, 61% and above. Although a minimum 50% mark was considered as a passing threshold, participants with less than 50% marks were included in the study to capture a holistic viewpoint. Then, a stratified purposive sampling was applied to select 30 students, maintaining representation from every stratum. Any student who refused to give informed written consent to take part in the study was excluded.

Study variable & data collection: The students were interviewed separately in a classroom setting using a self-administered questionnaire containing background information such as age (in completed years) and sex, etc. At the start of the interview, participants were assured of total anonymity and that their inputs would not affect their academic assessment. Because outside the scope of this work, researchers were directly involved in the teaching of the participants. It was done to minimize student-teacher hierarchy bias. The interview was followed by two independent tasks. First one being a constrained ranking exercise, where the participant is provided with a list of NMC-mandated 20 subject domains in undergraduate community medicine and asked to rank them in descending order of perceived difficulty, such that 1 = most hard domain and 20 = the easiest domain. (9) The second exercise was unrestrained pile sorting, where the participants were provided with 20 physical cards, each containing a subject domain. They were then asked to group the cards into piles based on perceived similarity. Following this, they were also told to note down the justification behind such grouping and any respective remedial suggestion, if any. Unlike traditional cultural domain analysis, which typically uses a sequentially dependent free-listing and pile-sorting workflow, this study separates the two exercises into independent tasks: a constrained ranking task and an unconstrained pile sort. Traditional free listing adds extraneous cognitive load to the participant and is highly susceptible to cognitive omission and recency bias. Participants may fail to elicit a specific subject domain not due to its perceived difficulty or simplicity, but merely due to a lack of recent exposure or recall fatigue.[10] By replacing free listing with a constrained ranking task, participants are structurally required to perform a comprehensive evaluation of all 20 NMC-mandated subject domains.[11] Furthermore, because the subsequent unrestrained pile sort is not restricted by a prior participant-generated free-list, it ensures that every NMC-mandated domain is uniformly evaluated for conceptual similarity across all study subjects.[6] Each data collection session lasted five to ten minutes. It was collected in the presence of SHR. There was no repeat data collection.

Data analysis: Basic socio-demographic data were entered and analysed by MS Excel 2021. For cultural domain analysis, Visual Anthropac and R version 4.3.2. were used. For constrained ranking analysis, a domain-wise Perceived Difficulty Score was derived mathematically by subtracting the mean difficulty rank assigned by all participants across each domain from the maximum baseline value, such that higher numerical scores strictly reflect greater collective perceived difficulty. A scree plot was used to classify the domains based on difficulty rank. For unrestrained pile sorting analysis, multidimensional scaling (MDS) and hierarchical cluster analysis (HCA) were done to identify the groups of conceptually similar domains. Additionally, manual thematic analysis was done to identify the reasons for such grouping and respective remedial measures. Initially, codes and themes were generated independently by SHR and SD. To establish qualitative rigor and inter-rater reliability, initial codebooks were compared, yielding an inter-rater agreement of 88% (Cohen's kappa = 0.82), indicating strong inter-coder reliability. Any conflict was resolved by the second author, SR. All three of them were trained in qualitative research.

Ethical Consideration: This study is approved by the Institutional Ethics Committee (IEC) of Sarat Chandra Chattopadhyay Govt. Medical College and Hospital, Uluberia. Informed written consent was obtained from all the participants. There was less than minimal risk associated with participation in this study.

RESULTS

Among the 30 phase III MBBS study participants, the median age was 22 (21, 23) years. Among them, 50% were male. Based on the last internal assessment marks 14 students (46.7%) got below 50%, 11 students (36.7%) got 50 to 60%, and five students (16.7%) got more than 60% marks out of 200. Non-response was minimal; out of 32 students approached, only two denied participating.

These 20 subject domains were classified into eight distinct difficulty categories through a structured breakpoint (or "elbow") analysis of their perceived difficulty rank, which are plotted in descending order.[12] By identifying the sharp transitions and flat plateaus along this mathematical curve, the domains are clustered into homogeneous tiers based on collective respondent consensus and median perceived difficulty rank 9.8 (8.6, 11.1). [Table 1 and Figure 1]

Extreme Bottleneck (>11.1): "Biostatistics and its Applications" stood out prominently at the apex of curriculum difficulty, possessing the highest perceived difficulty score of 13.03. It was followed by "Epidemiology of Communicable & Non-communicable Diseases" (Score: 12.47), "Health Planning and Management" (Score: 11.90) and "Epidemiology" (Score: 11.33), "Reproductive, Maternal, and Child Health" (Score: 11.20) and "Demography and Vital Statistics" (Score: 11.17).

Table 1: Perceived difficulty of NMC-mandated subject domains in community medicine (n = 30)

No.	Subject Domain	Sum of Ranks	Average Rank	Perceived Difficulty Score	Domain-wise Perceived Curricular Nature*
1	Biostatistics and Its Applications	239	7.97	13.03	Extreme Bottleneck
2	Epidemiology of Communicable & Non-communicable Diseases	256	8.53	12.47	Extreme Bottleneck
3	Health Planning and Management	273	9.10	11.90	Extreme Bottleneck
4	Epidemiology	290	9.67	11.33	Extreme Bottleneck
5	Reproductive, Maternal, and Child Health	294	9.80	11.20	Extreme Bottleneck
6	Demography and Vital Statistics	295	9.83	11.17	Extreme Bottleneck
7	Nutrition	311	10.37	10.63	Moderately high Difficulty
8	Health Care of the Community	316	10.53	10.47	Moderately high Difficulty
9	Recent Advances in Community Medicine	318	10.60	10.40	Moderately high Difficulty
10	Principles of Health Promotion and Education	330	11.00	10.00	Moderately high Difficulty
11	Relationship of Social and Behavioral Factors	338	11.27	9.73	Moderate-Low Difficulty
12	International Health	344	11.47	9.53	Moderate-Low Difficulty
13	Geriatric Services	349	11.63	9.37	Moderate-Low Difficulty
14	Environmental Health Problems	350	11.67	9.33	Moderate-Low Difficulty
15	Essential Medicine	358	11.93	9.07	Moderate-Low Difficulty
16	Concept of Health and Disease	385	12.83	8.17	Low Difficulty
17	Occupational Health	400	13.33	7.67	Low Difficulty
18	Mental Health	407	13.57	7.43	Low Difficulty
19	Hospital Waste Management	419	13.97	7.03	Low Difficulty
20	Disaster Management	428	14.27	6.73	Low Difficulty

Classification based on median perceived difficulty score 9.8 (8.6, 11.1)

Moderate-High Difficulty (9.8 – 11.1): Four domains populated this category: "Nutrition" (Score: 10.63), "Health Care of the Community" (Score: 10.47), "Recent Advances in Community Medicine" (Score: 10.40), and "Principles of Health Promotion and Education" (Score: 10.00).

Moderate-Low Difficulty (8.6 – 9.79): This band comprised five separate domains: "Relationship of Social and Behavioral factors" (Score: 9.73), "International Health" (Score: 9.53), "Geriatric Services" (Score: 9.37), "Environmental Health Problems" (Score: 9.33), and "Essential Medicine" (Score: 9.07).

Low Difficulty (< 8.6): Five areas were identified by students as low difficulty: "Concept of Health and Disease" (Score: 8.17), "Occupational Health" (Score: 7.67), "Mental Health" (Score: 7.43), "Hospital Waste Management" (Score: 7.03), and "Disaster Management" (Score of 6.73).

The two-dimensional (2D) multidimensional scaling for 20 subject domains showed a Kruskal's stress value of 0.185, borderline fit within the standard bounds of 0.15 to 0.20, indicating that while there is a minor localized distortion in compressing 20 complex dimensions into a 2D map, the macro-level spatial relationships and proximity boundaries between clusters remain highly stable and mathematically reliable for education planning.[13–16] Hierarchical Cluster Analysis (HCA) utilizing Ward's Minimum Variance Linkage partitioned the curriculum domains into four distinct conceptual thematic clusters [Table

2]. The absolute spatial layout and proximity boundaries are displayed in the MDS statistical map0 [Figure 2]. The dimensions and poles of the two-dimensional Multidimensional Scaling (MDS) map were labelled post-hoc by analysing the shared conceptual themes of the subject domains that sit at the extreme ends of each axis. Because MDS algorithms plot items based purely on geometric distance without providing pre-determined names for the axes, the labelling process relies on identifying the underlying cognitive vectors participants used to separate the domains during the pile-sorting task.

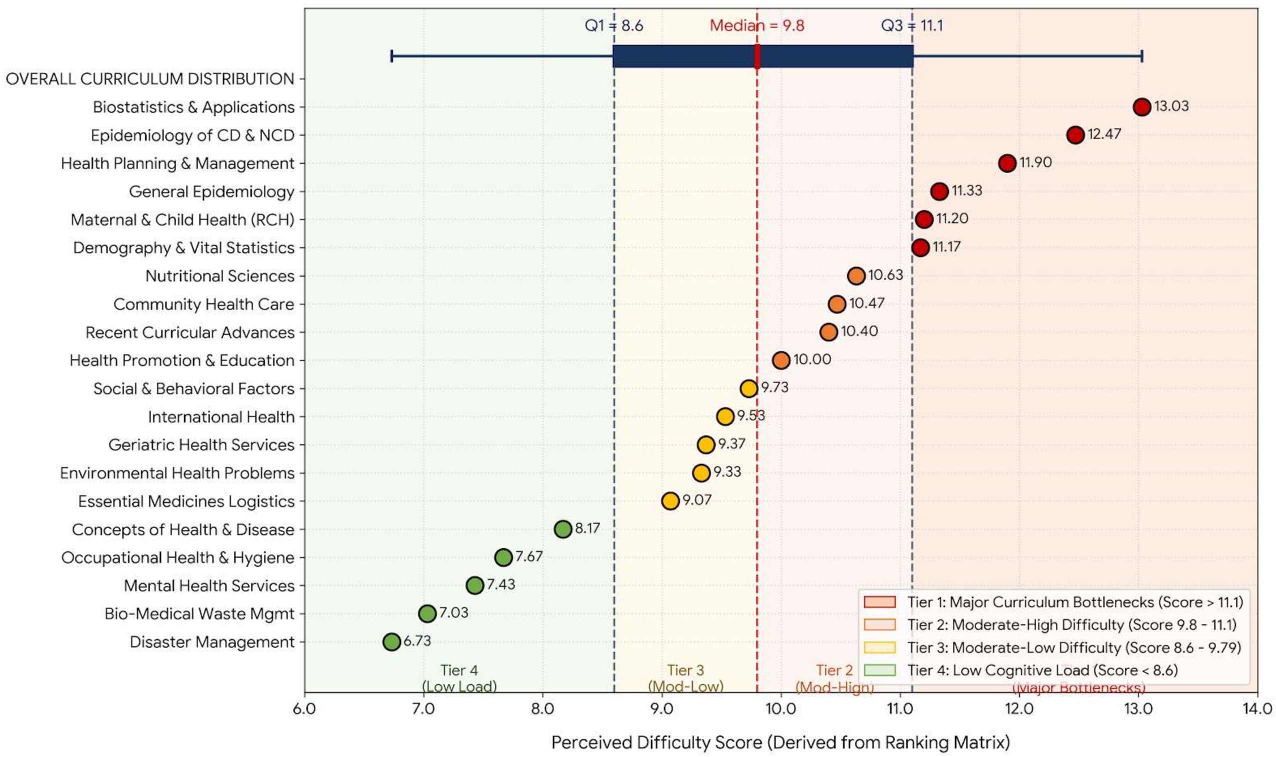

Figure 1: Box plot showing median-based categorization of subject domains

Dimension 1, the horizontal axis, represents an Analytical–Managerial Continuum that captures how public health work is executed. Moving from left to right, the axis transitions from data-driven, highly quantitative fields like Biostatistics, Demography, and Epidemiology on the negative end, to systems-driven, organizational domains like Health Planning, Medicine Logistics, and WHO guidelines on the positive end.

Dimension 2, the vertical axis, represents an Ecological–Lifecycle Continuum that captures the target scale of the health interventions. The upper half of this axis focuses on micro-level human biology and specific vulnerability stages across the lifespan, including Maternal and Child Health (RCH), Geriatrics (Old), and Nutrition. Conversely, the lower half shifts entirely to macro-level, external determinants and structural safety frameworks that exist outside the individual human body, such as Sanitation (Env), Occupational Health, Bio-Medical Waste, and Disaster Management.

The four strategic poles define the extreme outer boundaries of this cognitive space and were named by synthesizing the specific characteristics of the clusters generated via Hierarchical Ward's Linkage in each corner of the map.

Pole A, situated on the far left, is designated as the Analytical/Quantitative pole, as it is anchored by data-heavy subjects that rely strictly on mathematical modeling and epidemiological investigation.

Directly opposite on the far right sits Pole B, the Managerial/Operational pole, which clusters administration-heavy subjects dealing with the functional machinery, governance, and delivery of health systems.

Vertically, Pole C occupies the absolute peak of the map as the Micro-Targeted Human Care pole, bringing together subjects dedicated to directly supporting and treating individual human bodies at vulnerable stages of life.

Anchoring the base of the map is Pole D, the Macro-Environmental Systems pole, which groups together the subjects responsible for managing physical, structural, and environmental hazards across entire communities.

Together, these dimensions and poles demonstrate that the participants' mental framework for the curriculum is structured around two clear choices: whether a subject is mathematical versus administrative, and whether it treats a person versus the broader environment [Figure 2]. The mathematical cluster distribution and hierarchical distances are depicted in the conditional dissimilarity dendrogram [Figure 3].

The four statistical clusters of subject domains, along with the recommendations provided by the participants, were as follows [Table 2 & Figure 2].

Table 2: Subject domain clusters and thematic analysis (n = 30)

Subject Domain Clusters:	Subject Domains	Average perceived difficulty	Underlying reasons	Solution
Cluster A: Core epidemiology and Quantitative methods	Biostatistics, Epidemiology, Communicable and Non-communicable disease, Demography	12 (Hard most area)	An analytical thinking-based cognitive barrier High cognitive load Frequent updates	Use of graphs, flowcharts, & Concept maps Frequent practice Revise and active recall Update board Integrated teaching
Cluster B: Environmental & Occupational health infrastructure	Environment, Occupational Health, Hospital waste management, Disaster management	7.69 (Easiest area)	Easier to understand Lower cognitive load	Self-directed learning and subsequent evaluation
Cluster C: Health administration, system, and policy	Planning and management, International health, Essential medicine, recent advances	10.26 (Moderately hard)	Absence of clinical correlation Cognitive barrier	Image-based learning Problem-based learning Student seminar Audio-visual teaching methods
Cluster D: Family Health, Lifestyle, and Behavioral Science	Health, Sociology, Health promotion and education, Reproductive and child health, Nutrition, Geriatric health, Mental health	9.5 (Moderately hard)	High cognitive load, Less perceived importance Theoretical nature	Frequent evaluation Compartmentalization & Summarization Field visit Case-based learning Integrated teaching Fact sheet creation Peer-based mentoring

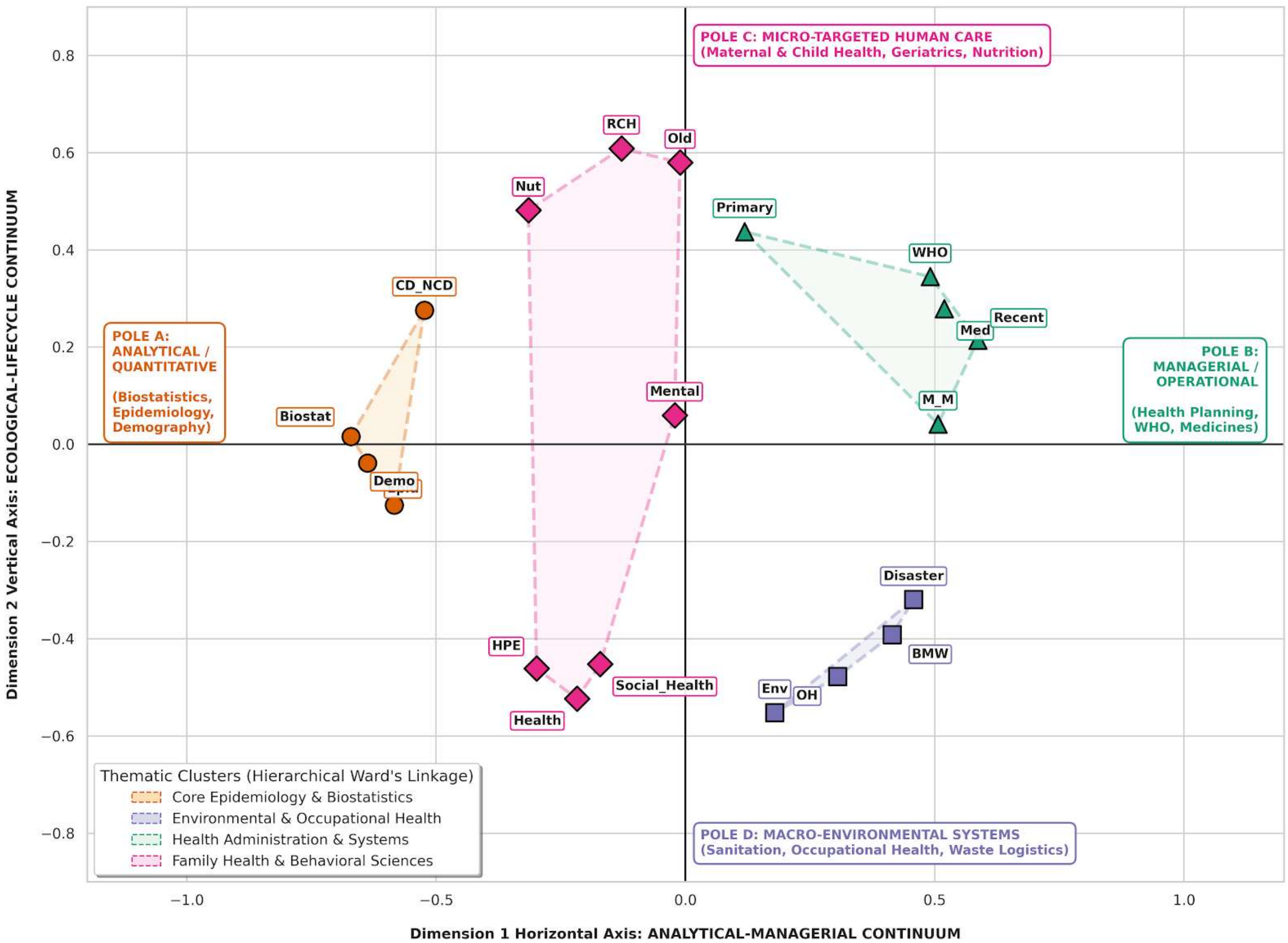

Figure 2: Multidimensional scaling statistical maps showing subject domain clusters

Cluster A (Core Epidemiology and Quantitative Methods): This cluster map captured the highest average perceived difficulty (Score: 12.00), integrating the extreme bottleneck and great difficulty domains of Biostatistics, Epidemiology, Communicable and Non-communicable disease, and Demography. Students identified analytical thinking-based cognitive barriers and an exceptionally heavy cognitive load as primary bottlenecks. To mitigate these issues, students proposed highly structured solutions: utilizing graphs, flowcharts, and visual concept maps, alongside frequent practical exercises, active recall tools, update boards, and integrated medical teaching. (*"Biostatistics feels completely disconnected from clinical medicine; we are memorizing formulas and p-values without understanding how they apply to a real patient in front of us."* 22 years, female)

Cluster B (Environmental & Occupational Health Infrastructure): Emerging as the least complex curricular block, this cluster had an average perceived difficulty score of 7.69, combining low, minimal, and easiest domains like Environment, Occupational Health, Hospital waste management, and Disaster management. Students noted that these domains are inherently easier to comprehend and carry a lower cognitive load, making them ideal candidates for self-directed learning modules followed by targeted subsequent evaluations. (*"Topics like biomedical waste or disaster response are very intuitive and* *straightforward—we can easily study these on our own using online modules rather than sitting through long didactic lectures."* 24 years, male)

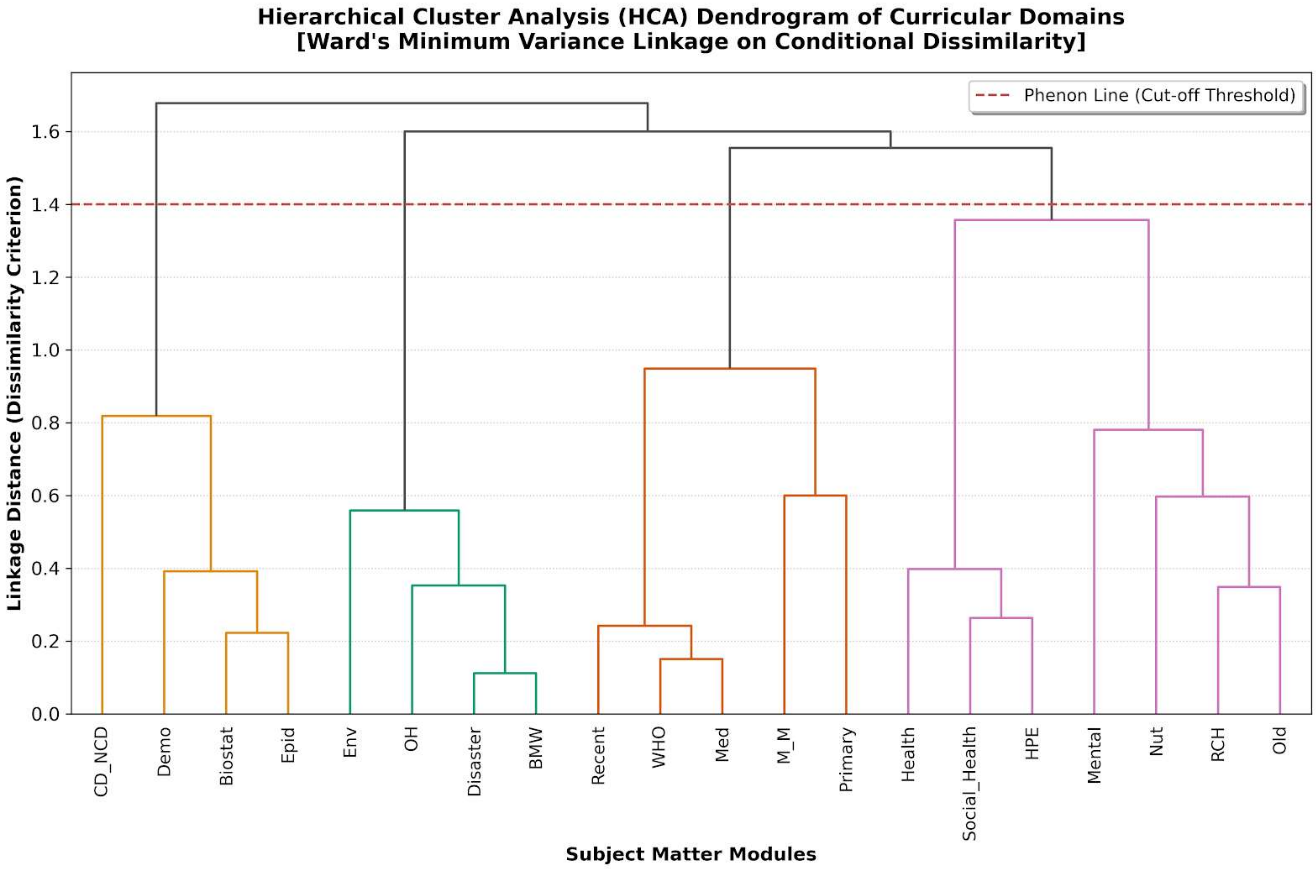

Figure 3: Conditional dissimilarity dendrogram showing mathematical cluster distribution and hierarchical distances

Cluster C (Health Administration, System, and Policy): This cluster fell into the moderately hard tier with an average score of 10.26, encompassing planning and management, international health, essential medicine, and recent advances. The qualitative analysis revealed that the absence of direct clinical correlations acts as a distinct cognitive barrier. Students recommended transitioning toward active, problem-based learning (PBL), utilizing image-based and audio-visual teaching methods, and incorporating student-led seminars to bridge this gap. (*"When we study health planning or the organizational structure of the WHO, it feels incredibly dry and abstract because we cannot visualize how it impacts our daily work in the hospital wards."* 22 years, male)

Cluster D (Family Health, Lifestyle, and Behavioral Science): Perceived as a moderately hard aggregate block (Score: 9.50), this extensive cluster spans health, sociology, Health promotion and education, Reproductive and child health, nutrition, geriatric health, and mental health. It shows a compounding high cognitive load, an overly theoretical content nature, and a low perceived clinical importance among learners. To structurally resolve these challenges, the thematic analysis outlined a multidimensional remedial blueprint: frequent structural milestone evaluations, content compartmentalization/summarization, experiential field visits, case-based clinical learning, horizontal/vertical teaching integration, quick-reference fact sheet generation, and peer-based student mentoring networks. (*"Programs like RCH and nutrition are very important, but the sheer volume of demographic targets and theoretical guidelines makes it overwhelming to revise before exams."* 21-year-old female)

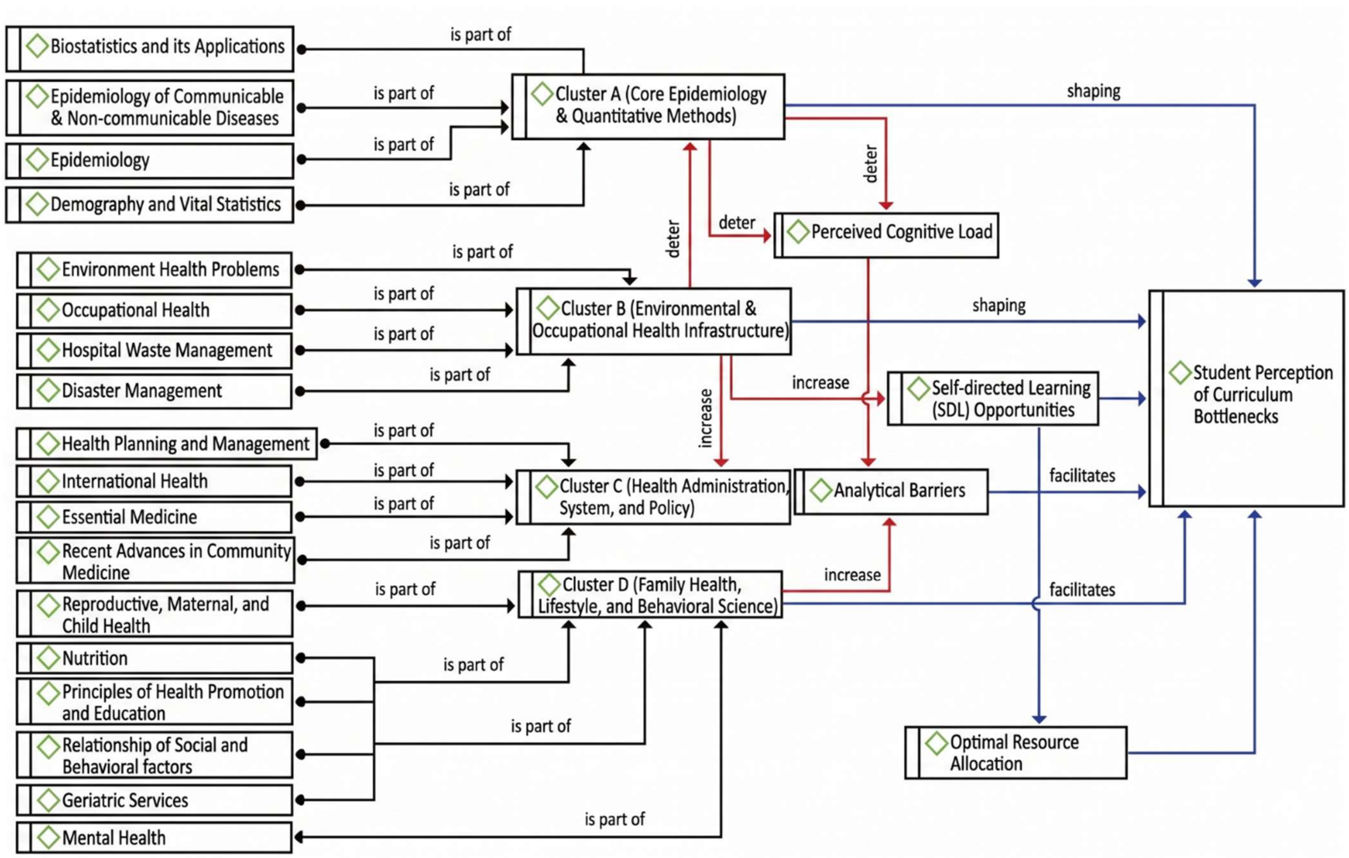

Figure 4: Qualitative thematic framework and cognitive mapping of curriculum bottlenecks in Community Medicine

DISCUSSION

The present study offers a novel framework for understanding how undergraduate medical students navigate the 136-competencies mandated by the NMC guidelines. (1) Stepping away from the traditional cultural domain analysis workflow into independent constrained ranking and unconstrained pile sorting tasks, we successfully mitigated cognitive omission and recency biases. (9) We created a multi-dimensional cognitive map of curriculum bottlenecks and four conceptual thematic clusters within Community Medicine, described below according to the descending order of average perceived difficulty score of each cluster.

Quantitative Bottlenecks and Analytical Barriers: Cluster A Cluster A, designated as Core Epidemiology and Quantitative Methods, emerged as the most formidable academic hurdle, commanding the highest average perceived difficulty score (Score = 12.00). At the absolute apex of this cluster sat "Biostatistics and its Applications," identified as an extreme bottleneck (Score = 13.03, S = 0.652). This distinct difficulty profile stems from an analytical thinking-based cognitive barrier. Medical undergraduates traditionally demonstrate lower baseline affinity or training in mathematical modelling and statistical reasoning, creating an immediate friction point when transitioning to quantitative health evaluation.[17,18]

Furthermore, this cluster integrates "Epidemiology of Communicable & Non-communicable Diseases" and "Epidemiology," both categorized as high-difficulty domains. Students identified an exceptionally heavy cognitive load driven by the sheer mass of programmatic details, diagnostic criteria, and shifting operational guidelines. Because undergraduate students operate largely in tertiary institutional settings, they experience limited firsthand exposure to the grassroots execution of these National Health Programs.[2,19] This lack of field-level contextualization obscures their capacity to prioritize critical concepts, leading to recall fatigue.

These findings suggest a strong student preference for visual scaffolding in quantitative domains, providing a hypothesis for future controlled trials testing this specific intervention. Furthermore, implementing simultaneous horizontal and vertical integration with foundational subjects like Microbiology can reconcile conceptual conflicts. To combat the "shadow of belated guidelines" caused by frequent programmatic changes, institutions should establish physical or virtual dynamic update boards. Finally, leveraging active learning through observation of public health days (e.g., World Health Days), including student-mediated chart and poster presentations, can significantly improve student engagement and long-term memory retrieval. [Figure 4]

The Problem of Disconnected Governance: Cluster C Cluster C (Health Administration, System, and Policy) occupied a moderately hard tier within the curriculum (Score = 10.26), binding together planning and management, international health, essential medicine, and recent advances. The qualitative findings highlighted a distinct cognitive barrier: the total absence of direct clinical correlations within these domains. Medical undergraduates are fundamentally conditioned to prioritize diagnostic and therapeutic clinical pathways, and under CBME 2024 phase III, MBBS students are heavily exposed to wards; their cognitive scaffolding is completely patient centred. Consequently, they struggle to find relevance in abstract macroscopic concepts like health governance, healthcare financing, and organizational infrastructure, and feel completely disconnected because they cannot be immediately applied at a patient's bedside. It triggers an 'abstractness block'.[20,21]

To bridge this operational gap, the instructional architecture must transition toward active, problem-based learning (PBL) modules. Pedagogical tools such as administration-themed role-plays can simulate real-world healthcare management scenarios, effectively linking health policy to clinical outcomes. Furthermore, utilizing image-based learning cues, audio-visual materials, and faculty-guided student seminars can ground these abstract administrative concepts into tangible, highly scannable mental frameworks. [Figure 4]

The Challenge of Exhaustive Theory: Cluster D Perceived as a moderately hard aggregate block (Score = 9.50), Cluster D (Family Health, Lifestyle, and Behavioral Science) represents an extensive, content-heavy domain spanning sociology, reproductive and child health (RCH), health promotion & education, nutrition, geriatrics, and mental health, etc. This cluster presents a unique pedagogical paradox: while domains like RCH are deeply clinical, the overall cluster suffers from a low perceived clinical importance among learners due to its overly theoretical presentation in classrooms, compounding an unmanageable cognitive load.

To resolve these structural bottlenecks, a multidimensional remedial blueprint is required. First, structural content compartmentalization and summarization are essential to break down vast chapters into manageable units. Second, to capitalize on the clinical relevance of RCH and nutrition, traditional learning must be reinforced through experiential field visits and dedicated postings in antenatal, postnatal, and immunization clinics. These field exposures allow students to directly anchor theoretical models to real-world maternal and child cohorts.[22]

Additionally, creating high-yield, quick-reference "fact sheets" detailing vital statistics (e.g., maternal and infant mortality rates) can facilitate the rapid memorization of crucial numerical metrics. At an interpersonal level, establishing peer-based student mentoring networks can offer a low-stakes environment for collaborative learning, allowing students to navigate curricular gaps organically without the anxiety of immediate faculty assessment. This should be further paired with horizontal and vertical teaching integration during clinical rotations in Obstetrics & Gynecology and Pediatrics. [Figure 4]

Optimized Curricular Efficiency: Cluster B In stark contrast to the rest of the curriculum, Cluster B (Environmental & Occupational Health Infrastructure) emerged as the least complex curricular block (Score = 7.69). Combining domains like environmental health, occupational health, hospital waste management, and disaster management, students perceived these areas as inherently intuitive and structurally lower in cognitive load.

Recognizing Cluster B as a low-difficulty block opens a vital strategic opportunity for medical faculties facing resource constraints. Rather than exhausting valuable, limited lecture hours on highly comprehensible topics, these domains represent prime candidates for conversion into self-directed learning (SDL) modules along with a specific quality assurance framework in place. (23,24) This transition allows institutions to safely reallocate instructional capital and remedial attention toward high-difficulty bottlenecks like Cluster A, provided that the SDL modules are paired with structured, subsequent target evaluations to ensure accountability, such as mandatory post-module reflection logs or automated, low-stakes multiple-choice questions (MCQs) on the institutional learning system. (Figure 4)

Ultimately, across all four thematic clusters, the integration of frequent milestone evaluations and iterative practice remains a foundational requirement. Implementing routine, low-stakes formative assessments prevent cumulative cognitive decay and ensures that pedagogical interventions remain adaptive, data-driven, and equitably distributed across the student cohort.

Strengths & Limitations: This study used constrained ranking and unrestrained pile sorting, which helped to mitigate the recency and recall bias. Use of stratified purposive sampling gave a representative picture across all academic performance strata. Moreover, the use of HCA and MDS allows the creation of a specific, data-driven pedagogical blueprint, tailored for the unique cognitive barriers of each cluster. However, as an exploratory qualitative investigation, the study does not employ a traditional control group, focusing instead on internal consensus and shared cognitive structures among participants. A primary limitation is the study's institutional and geographic constraints, as it was conducted at a single medical college in Uluberia, West Bengal, with a sample size of 30 Phase III MBBS students. Secondly, ranking 20 separate domains simultaneously introduces a risk of cognitive exhaustion and 'satisficing'. It was a response bias where participants choose accurately at the top of the list but make arbitrary choices at the bottom. While a formal test-retest reliability was not performed, this limitation is mitigated by our dual-task design. The fact that the unconstrained pile sort clusters (like Cluster B) strongly align with the lower-ranked tiers, it suggests a genuine collective consensus. Nonetheless, future studies should incorporate explicit pilot testing, and reliability checks to further validate instrument stability. Also, when the “minimal difficulty” topics were converted into SDL, it is important to acknowledge that it don’t leads to superficial knowledge. The borderline MDS Kruskal stress value of 0.185 indicates a mediocre two-dimensional fit, indicating that while a macro-level cluster are reliable, the precise geometric distances between individual adjacent domains reflect some localized structural distortion. Lastly, These localized findings may not be fully generalizable to other medical institutions across India that feature different regional contexts, infrastructure, or student demographics. Additionally, despite translating subjective student experiences into an objective cognitive map using advanced statistical tools, the underlying data remains heavily reliant on self-administered questionnaires, self-perceived difficulty scores, and manual thematic interpretation by the authors. There is also a risk of selection bias due to the study's strict eligibility criteria; by restricting participation to students who maintained a minimum of 60% attendance in theory and practical classes, the study potentially omits the perceptions of chronically absent students who might experience entirely different or more severe curricular bottlenecks.

Future research should focus on validating these localized findings by replicating the modified cultural domain analysis framework across multiple diverse medical institutions across India to ensure broader generalizability beyond a single center. Longitudinal studies could also track whether deploying the recommended pedagogical interventions, such as self-directed learning for low-difficulty clusters and problem-based learning for analytical bottlenecks, tangibly reduces cognitive load and improves objective academic performance over time. Additionally, future research could incorporate faculty perspectives and performance data from university professional examinations to triangulate student perceptions with objective educational outcomes.

CONCLUSION

By mapping the cognitive topography of the NMC 2024 competency framework in community medicine, this study demonstrates that undergraduate medical students do not experience it as a uniform baseline but rather navigate distinct thematic tiers of cognitive complexity. The identification of "Biostatistics and its Applications" as an extreme analytical bottleneck, alongside the high-difficulty rating of programmatic core epidemiology, indicates an urgent pedagogical need to shift from passive lectures to active, visual, and integrated learning strategies. Conversely, the low perceived difficulty of the environmental health infrastructure cluster reveals a strategic opportunity for institutions to deploy self-directed learning modules. Ultimately, utilizing these data-driven insights enables medical faculties to optimize the use of limited instructional resources, design targeted remedial interventions, and dynamically reshape public health education to match the cognitive realities of modern medical trainees.

DECLARATIONS

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