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Outcome-Based Education in the Life Sciences: A Comprehensive Review of Undergraduate Botany and Zoology Curricula under NEP 2020

With Special Reference to Public Universities of North and North-West India (Himachal Pradesh, Punjab, Chandigarh, Haryana, Jammu & Kashmir, Ladakh, Uttarakhand, Rajasthan and Delhi)

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ABSTRACT

The National Education Policy (NEP) 2020 has re-oriented Indian higher education from a teacher-centric, content-delivery model toward a learner-centric, Outcome-Based Education (OBE) paradigm operationalised through the Four-Year Undergraduate Programme (FYUGP), the National Higher Education Qualifications Framework (NHEQF) and the Learning Outcomes-based Curriculum Framework (LOCF). It examines how OBE is embedded in undergraduate botany and zoology across public universities of nine north and north-west Indian states and union territories: Himachal Pradesh, Punjab, Chandigarh, Haryana, Jammu & Kashmir, Ladakh, Uttarakhand, Rajasthan and Delhi. It covers OBE's conceptual basis; the architecture of Programme, Programme-Specific and Course Outcomes, with CO–PO mapping and constructive alignment; and the credit menu of Major, Minor, Multidisciplinary, Ability, Skill and Value-Added Courses. It rates institutional systems on outcome articulation, practical and field training, assessment maturity, CO–PO mapping and NEP alignment, and proposes an original Integrated Life-Sciences OBE (ILS-OBE) framework linking curriculum, pedagogy, assessment, infrastructure, industry–community linkage, graduate attributes and quality improvement. Two discipline-specific transitions receive attention: "plant blindness", and zoology practicals after the restriction of dissection. Every rating rests on the institution's own documents, several published only as unsearchable scans. The central finding is negative and general: not one curriculum examined publishes a CO–PO matrix, an attainment target or a rubric, and most carry no programme-outcome tier, including the most-cited exemplars. Structural convergence is substantial, but the apparatus that would make outcomes measurable is largely unbuilt, and attainment depends less on syllabus design than on faculty capacity, practical infrastructure and the integrity of the attainment cycle.

1. Introduction

The life sciences, botany, the science of plant life, and zoology, the science of animal life, occupy a foundational position in the biological sciences and in the applied domains of agriculture, forestry, fisheries, animal husbandry, pharmacy, biotechnology, environmental management, public health and food security. Yet both disciplines carry historic problems of perception and pedagogy. Botany has long struggled with "plant blindness", the tendency of learners and curricula to overlook plants relative to animals (Wandersee & Schussler, 1999, 2001; Balding & Williams, 2016). Zoology faces a parallel distortion: student conceptions of "animal" are dominated by charismatic vertebrates, especially mammals, while the invertebrate majority of animal diversity is neglected, and whole-organism, comparative and field zoology have receded before molecular and biomedical framings. Both traditions have prized coverage over capability, teaching through lecture-and-list rather than investigation (Hershey, 1996; Uno, 2009). For much of the twentieth century, undergraduate botany and zoology in India were taught through a syllabus-driven model in which the primary question asked of a graduate was what has been covered rather than what the graduate can now do. Outcome-Based Education (OBE) inverts this logic. It begins with a clear articulation of the abilities, dispositions and competencies a learner should demonstrably possess at the point of exit, and works backward, designing courses, learning experiences, laboratory work and assessment so that every element contributes to the attainment of those declared outcomes (Spady, 1994; Harden, 1999; Biggs & Tang, 2011).

The National Education Policy 2020 formalised this shift at the national level (MHRD, 2020). It frames curriculum reform around graduate attributes and learning outcomes, and its implementing instruments, the University Grants Commission's Curriculum and Credit Framework for the FYUGP (UGC, 2022), the NHEQF (UGC, 2023) and the LOCF (UGC, 2019), translate policy into a credit architecture and an outcome vocabulary that every university must adopt. For laboratory- and field-intensive disciplines such as botany and zoology, this transition carries both promise and difficulty: promise, because the life sciences are naturally suited to experiential, skill-rich and observation-driven learning (Sundberg & Moncada, 1994; Hofstein & Lunetta, 2004; AAAS, 2011); difficulty, because measuring the attainment of such outcomes demands rigour, infrastructure and faculty capacity that many institutions are still building. Zoology carries an additional, distinctive constraint: following sustained advocacy and the University Grants Commission's decision to restrict and phase out animal dissection and experimentation in undergraduate and postgraduate zoology and life-sciences courses (Akbarsha, 2007; UGC, 2014), animal practicals have been reconfigured around museum specimens, permanent slides, models, virtual dissection and field observation, a change that, handled well, aligns closely with OBE's emphasis on authentic, ethically defensible and observation-led skill development.

This article reviews the conceptual basis of OBE together with the concrete curricular practice now emerging in undergraduate botany and zoology across the public universities of nine states and union territories of north and north-west India: Himachal Pradesh, Punjab, Chandigarh (UT), Haryana, Jammu & Kashmir, Ladakh (UT), Uttarakhand, Rajasthan and Delhi. It has five aims: to make the review method transparent; to analyse the outcome architecture of POs, PSOs and COs for the plant and animal sciences; to compare and critically evaluate the life-sciences curricula of the focal public universities; to synthesise strengths, weaknesses, trends and unresolved issues across them; and to propose an original, integrative framework for outcome-driven life-sciences education. In doing so it moves deliberately beyond description toward analysis, synthesis and design, and treats botany and zoology as complementary halves of a single organismal-biology education rather than as isolated subjects.

The literature on which this review builds is, however, uneven in a specific and consequential way. Existing scholarship on outcome-based education is strong on conceptual foundations and on professional-programme implementation: the origins, theory and empirical warrant of the paradigm have been examined in depth (Spady, 1994; Harden, 1999; Morcke et al., 2013), constructive alignment and outcome articulation are well theorised (Biggs, 1996; Biggs & Tang, 2011), and accreditation-driven accounts of CO–PO mapping and attainment computation are available for Indian engineering and technical education in particular (NBA, 2013; Rao, 2020). Alongside this, a separate body of discipline-specific work addresses the pedagogical pathologies of the life sciences, plant blindness and botanical literacy on one side (Wandersee & Schussler, 1999, 2001; Uno, 2009; Balding & Williams, 2016; Sanders, 2019), and the ethics and practical consequences of dissection reform on the other (Akbarsha, 2007; UGC, 2014), but does so largely without reference to the outcome architecture now mandated nationally. What is missing is the connection between the two: no comprehensive comparative analysis has yet examined how OBE is actually being implemented in undergraduate botany and zoology curricula across the public universities of north and north-west India, a region whose institutions span research-intensive central universities, early-adopting state universities and large affiliated teaching networks, and whose biota range from alpine and temperate Himalayan systems to arid-zone desert ecology. Nor has the existing literature treated botany and zoology as two halves of a single organismal-biology education whose outcome structures, practical transitions and infrastructure constraints are best understood together rather than separately. This review addresses that gap by combining a transparent, document-based comparative analysis of the focal universities' published NEP-era curricula with a critical synthesis of strengths, weaknesses and unresolved issues, and by proposing an integrative framework (ILS–OBE) that connects outcome design, pedagogy, assessment, infrastructure and continuous quality improvement to the regional biodiversity context in which these curricula are actually taught.

2. Review Methodology

This is a narrative-cum-comparative review (Grant & Booth, 2009): it retains the interpretive latitude of a narrative synthesis while adopting an explicit, reproducible search-and-selection procedure so that readers can judge the basis of its claims. The procedure is summarised below and in Table 1.

2.1 Search sources

Evidence was drawn from four source types. First, policy and regulatory documents: NEP 2020 (MHRD, 2020) and the UGC frameworks for the FYUGP, NHEQF and LOCF (UGC, 2019, 2022, 2023), the National Board of Accreditation OBE manual (NBA, 2013), and the UGC guidelines restricting animal dissection in zoology and life-sciences courses (UGC, 2014). Second, official university sources: the websites, syllabus repositories and NEP portals of the focal public universities, covering both botany and zoology syllabi. Third, scholarly databases: Google Scholar, Scopus and Web of Science, supplemented by ERIC for education literature. Fourth, discipline-specific journals in biology and science education, including CBE-Life Sciences Education, The American Biology Teacher, Journal of Biological Education, American Journal of Botany, Science Education, Studies in Higher Education, and journals addressing animal-biology pedagogy and alternatives to animal use in education (e.g., ALTEX).

2.2 Keywords and search strings

Boolean combinations of the following terms were used: (“outcome-based education” OR “OBE” OR “learning outcomes” OR “competency-based education”) AND (“botany” OR “plant science” OR “zoology” OR “animal science” OR “life sciences” OR “biology education” OR “undergraduate science”) AND (“NEP 2020” OR “FYUGP” OR “NHEQF” OR “curriculum framework”), together with focused strings on “course outcomes”, “CO–PO mapping”, “Bloom’s taxonomy”, “constructive alignment”, “laboratory education”, “dissection alternatives”, “virtual dissection”, “inquiry-based learning”, “active learning”, “assessment”, “attainment” and “employability”. University-specific searches paired each institution’s name with “botany syllabus”, “zoology syllabus” and “NEP”.

2.3 University selection

Universities were selected purposively against four criteria: (a) public funding (state or central), private and deemed universities being cited only illustratively; (b) delivery of botany and/or zoology at the undergraduate level; (c) a publicly available NEP-aligned curriculum; and (d) a significant teaching footprint, particularly an affiliating role over government and aided colleges. Because botany and zoology are almost universally offered together within the same faculties of science and the same NEP credit architecture, the selected institutions serve as common referents for both disciplines. The resulting set spans the nine focal states and union territories and is representative rather than exhaustive.

2.4 Inclusion and exclusion criteria

Inclusion: English-language sources; foundational pedagogy and assessment literature from 1949 (Tyler) to 2025; the Indian NEP corpus and university syllabi (botany and zoology) from 2020–2025; peer-reviewed articles, scholarly books, official policy documents and university curricular documents. Exclusion: pre-NEP Indian syllabi (except where cited for historical contrast); non-life-sciences and school-level materials; private/deemed-university syllabi except as illustration; and non-verifiable, predatory or unattributed web content.

Source documents were of two kinds, and the distinction is material to how the comparative judgements in Sections 5 and 6 should be read. For the majority of the focal institutions, primary curricular documents were available in machine-readable form and were analysed directly: the University of Delhi's Undergraduate Curriculum Framework 2022 syllabi, notified by amendment to Ordinance V for semesters I–II (2023), IV–VI (6 October 2023) and VII–VIII (31 July 2025), together with the Semester VIII assessment guidance of 9 January 2026 (University of Delhi, 2023, 2025, 2026), Panjab University's NEP curriculum and credit framework (Panjab University, 2023), Himachal Pradesh University (2023), Kurukshetra University (2023), Guru Nanak Dev University (2024), the University of Jammu (2022), the University of Rajasthan (2024), Hemvati Nandan Bahuguna Garhwal University (2025), the Central University of Punjab (2021) Kumaun University (2022), the University of Kashmir (2023, 2025), Pandit Deendayal Upadhyaya Shekhawati University (2024) and Maharaja Ganga Singh University (2025). A third category proved material in practice: several institutions publish curricular documents only as image scans with no text layer, including the University of Jammu's honours semesters V-VIII and all five Shekhawati University documents. These were recovered by page rendering and transcription and are treated as directly analysed, but the fact that they are published in a form no reader can search is itself evidence bearing on the documentary opacity discussed in Section 12. One document, a B.Sc. zoology scheme for session 2025-26 sharing the examination architecture and regional content of the Maharaja Ganga Singh University botany scheme, carries no institutional name on any page; its attribution to that university was confirmed by the author and is recorded as author-confirmed rather than document-verified. Where an institution's syllabi were available only as scanned, partially rendered or non-extractable files, or where a document covered programme structure without publishing course-level outcome statements, three national reference documents were used in their place to characterise the typical outcome and assessment architecture of NEP-era botany and zoology provision: the UGC's Learning Outcomes-based Curriculum Framework for undergraduate programmes, including its subject templates for botany and zoology (UGC, 2019); the UGC Curriculum and Credit Framework for Undergraduate Programmes (UGC, 2022), which fixes the credit structure and course-basket nomenclature; and the National Higher Education Qualifications Framework (UGC, 2023), which supplies the level descriptors against which programme outcomes are calibrated. These national documents were used only to describe the generic structure that universities are required to adopt. No institution-specific claim in this review, including every rating recorded in Table 4, rests on them: all institution-level statements about outcome articulation, practical and field provision, assessment structure, CO–PO mapping or NEP alignment are drawn from that institution's own publicly available curricular documentation, and where such documentation was silent on a dimension, that dimension is reported as not publicly documented rather than inferred.

2.5 Years covered

Conceptual and pedagogical literature spans 1949–2025 to capture the lineage from Tyler’s rationale through Bloom, Spady, Biggs and contemporary biology-education reform. Policy and curricular sources are concentrated in 2020–2025, the active NEP-implementation window; individual university syllabi range from 2021 (early adopters) to 2025 (most recent revisions). The dissection-reform literature is drawn from 2007 onward, tracking the regulatory changes that reshaped zoology practicals.

2.6 Analysis framework

Sources were analysed thematically through five lenses, (1) outcome architecture, (2) curriculum structure, (3) pedagogy, (4) assessment and attainment, and (5) skills and employability, using constructive alignment (Biggs, 1996) and Bloom's revised taxonomy (Anderson & Krathwohl, 2001) as the interpretive scaffold, applied even-handedly to plant and animal sciences. On this basis the review then performs a comparative rating of flagship systems (Section 6), an evidence synthesis of cross-cutting patterns (Section 7), and the construction of an integrative framework (Section 11). Comparative ratings are indicative judgements grounded in publicly available curricular documentation as of 2024–2025, not primary attainment audits.

Table 1. Summary of the review methodology.

Element	Description
Review type	Narrative-cum-comparative review with explicit search protocol (Grant & Booth, 2009)
Search sources	UGC portal & frameworks; NEP 2020 and NHEQF/LOCF documents; UGC dissection-reform guidelines; official university websites & NEP syllabus portals (botany & zoology); Google Scholar, Scopus, Web of Science, ERIC; biology/science-education journals including ALTEX
Keywords	OBE, learning/course outcomes, CO–PO mapping, Bloom's taxonomy, constructive alignment, NEP 2020, FYUGP, botany/plant-science & zoology/animal-science education, laboratory & inquiry learning, dissection alternatives, competency, assessment, employability (Boolean AND/OR)
Selection criteria	Public (state/central) universities; UG botany and/or zoology offered; NEP-aligned curriculum publicly available; affiliating/major teaching role
Inclusion	English sources; pedagogy literature 1949–2025; NEP corpus & syllabi (botany & zoology) 2020–2025; peer-reviewed articles, books, policy & curricular documents
Exclusion	Pre-NEP syllabi (except historical contrast); non-life-sciences/school-level; private-deemed syllabi (illustrative only); non-verifiable/predatory sources
Years covered	Conceptual literature 1949–2025; policy & syllabi 2020–2025; dissection-reform literature 2007 onward
Analysis framework	Thematic analysis on five lenses (outcomes, structure, pedagogy, assessment, employability) scaffolded by constructive alignment and Bloom, applied to plant and animal sciences; comparative rating + evidence synthesis + framework construction

3. The Conceptual Framework of Outcome-Based Education

OBE has deep roots in the curriculum tradition. Tyler's (1949) rationale first insisted that education begin with defined purposes and organise learning experiences and evaluation around them; Bloom's (1956) taxonomy gave those purposes a graded cognitive vocabulary; and Mager (1962) argued that instructional objectives must be behavioural and measurable. Spady (1994; Spady & Marshall, 1991) synthesised these strands into OBE proper, resting on four premises: clarity of focus on culminating outcomes, backward (reverse) design of the curriculum, high expectations of all learners, and expanded opportunity to demonstrate learning. Harden (1999; Harden, Crosby & Davis, 1999) carried OBE into professional education, and the model now overlaps substantially with competency-based education (Frank et al., 2010; Gervais, 2016; Morcke, Dornan & Eika, 2013).

The mechanism that turns outcomes into practice is constructive alignment (Biggs, 1996; Biggs & Tang, 2011; Biggs, 2014): intended learning outcomes, teaching-learning activities and assessment tasks are deliberately matched so that what is taught, how it is taught, and what is assessed all point at the same competency. Related design traditions, backward design (Wiggins & McTighe, 2005), significant learning (Fink, 2013) and course/curriculum design (Diamond, 2008; Toohey, 1999), converge on the same principle: a course is well aligned when its assessment cannot be passed without attaining its stated outcomes. This marks the wider shift from a teaching paradigm to a learning paradigm in higher education (Barr & Tagg, 1995; Ramsden, 2003).

The engine that makes outcomes writable and measurable is Bloom's revised taxonomy (Anderson & Krathwohl, 2001; Krathwohl, 2002), which arranges cognitive processes on an ascending ladder, remember, understand, apply, analyse, evaluate and create, each with observable action verbs; "Biology in Bloom" (Crowe, Dirks & Wenderoth, 2008) demonstrates its direct use in life-science course and assessment design across both plant and animal biology. Bloom's revised taxonomy is the framework in general use in Indian OBE practice and is adopted throughout this review, though alternative outcome taxonomies exist that give explicit place to metacognitive and self-regulatory dimensions the cognitive taxonomy leaves implicit (Marzano & Kendall, 2007). The life sciences draw on all three learning domains: the cognitive; the psychomotor (microscopy, sectioning, staining, mounting and field collection in botany; histological preparation, permanent-slide and museum work, whole-mount and model-based study, and specimen handling in zoology); and the affective (biodiversity ethics, conservation values, and, acutely in zoology, animal-welfare sensibility and the ethics of the "three Rs"; Krathwohl, Bloom & Masia, 1964; Akbarsha, 2007). Within NEP this taxonomy is embedded in a nested hierarchy, Graduate Attributes (Barrie, 2006) → Programme Outcomes → Programme-Specific Outcomes → Course Outcomes, with the NHEQF assigning descriptors and credit thresholds to each qualification level (4.5 for the certificate through 6.0 for the four-year honours-with-research degree), so that outcomes deepen as a student progresses.

4. The Outcome Architecture in NEP-Aligned Life-Sciences Curricula

4.1 Programme and Programme-Specific Outcomes

Programme Outcomes for undergraduate botany and zoology, as expressed across NEP-aligned syllabi, cluster around a recognisable set of organismal-biology competencies. In botany these include the ability to describe, identify and classify plant and microbial life forms using correct botanical terminology; to explain plant and microbial structure, life cycles and physiological processes through model organisms; to understand plant–microbe interactions and ecosystem dynamics; and to collect, preserve and record botanical information. In zoology the parallel outcomes are to describe, identify and classify animal life forms from protists and invertebrates to chordates using correct zoological terminology; to explain animal structure, development, physiology and behaviour through representative types; to understand animal–environment interactions, population and community ecology, and parasite–host relationships; and to observe, record and, within ethical and legal limits, document animal material. Both share the outcomes of interpreting variation and evolution through comparative morphological, anatomical, embryological, physiological, biochemical and molecular evidence, and of remaining aware of scientific and technological advances in the life sciences. To these are added transferable outcomes, critical and research-oriented thinking, knowledge of local flora and fauna and of ethnobiology, awareness of the economic and ecological contribution of plants and animals, and analytical and technical competence, mirroring the graduate attributes of communication, ethics, environmental sensitivity and lifelong learning that NEP emphasises (Barrie, 2006; Bridgstock, 2009).

PSOs sharpen these into the professional identity of a life-sciences graduate. For botany: the ability to design and perform experiments in plant physiology and biochemistry; to apply tools of plant tissue culture, microbiology and biotechnology; to conduct floristic surveys, prepare herbaria and maintain field records. For zoology: the ability to design and perform experiments in animal physiology, biochemistry and cell biology; to apply tools of histology, microtechnique, economic zoology (sericulture, apiculture, aquaculture) and animal biotechnology; to conduct faunal surveys, prepare and curate museum and slide collections, and maintain field and behavioural records using humane, non-invasive methods. Both point graduates toward higher study or employment in teaching, research, agriculture, horticulture, forestry, fisheries, animal husbandry, environmental consultancy, wildlife and conservation agencies, and allied industries. Well-drafted PSOs make the programme accountable to identifiable academic and career destinations rather than to an abstract body of content (Yorke, 2006; Tomlinson, 2012).

4.2 Course Outcomes and the CO–PO mapping matrix

Each course carries three to six Course Outcomes, phrased as “After completing this course, the student will be able to …” followed by a Bloom-aligned verb (Anderson & Krathwohl, 2001; Crowe et al., 2008). The pedagogical discipline of OBE lies not in writing these statements but in mapping them: each CO is linked to the POs and PSOs it advances, and the strength of each link is graded (1 = slight, 2 = moderate, 3 = substantial). Aggregated across all courses, these links form the CO–PO articulation matrix, which reveals whether every PO is adequately served and exposes gaps where an intended outcome is under-supported (NBA, 2013). Table 2 illustrates the mapping for two paired first-year courses, one in plant diversity and one in animal diversity, to show how the same mapping discipline applies across the two disciplines. It must be stated at the outset that Table 2 is constructed by the present authors as a normative illustration of the method described in the accreditation literature (NBA, 2013), and not extracted from any institution's published curriculum: as Section 6 documents, no undergraduate botany or zoology curriculum examined for this review publishes such a matrix.

Table 2. Illustrative CO–PO mapping for paired first-year plant-diversity and animal-diversity courses (3 = substantial, 2 = moderate, 1 = slight correlation). Constructed by the authors to demonstrate the method; not reproduced from any institution's published curriculum.

Course Outcome (illustrative)	PO1	PO2	PO3	PO4	PO5	PO6
Botany CO1: Classify major plant groups using botanical terminology	3	2	1	2	1	1
Botany CO2: Illustrate life cycles of algae, bryophytes and pteridophytes	2	3	2	3	2	1
Botany CO3: Perform hand-sectioning and microscopy of plant tissues	1	2	1	2	1	3
Botany CO4: Prepare and curate a herbarium of local flora	2	1	2	1	1	3
Zoology CO1: Classify major animal phyla using zoological terminology	3	2	1	2	1	1
Zoology CO2: Compare life cycles and development of representative invertebrates and chordates	2	3	2	3	2	1
Zoology CO3: Prepare and interpret permanent slides and study museum specimens/models	1	2	1	2	1	3
Zoology CO4: Conduct a faunal field survey using humane, non-invasive methods	2	1	3	1	2	3

Constructed honestly, such matrices become the backbone of continuous improvement: attainment data gathered against each CO roll up through the matrix to report PO attainment, and shortfalls are traced back to specific courses and remediated (NBA, 2013; Rao, 2020). Constructed mechanically, every CO conveniently mapped at strength 3 to every PO, they become a compliance ritual with no diagnostic value. Distinguishing the two is one of the central quality challenges of OBE in practice, and it is identical in botany and zoology.

The distinction is not a matter of intention but of documentary trace, and three checks separate a diagnostic matrix from a tokenistic one. First, distribution: a matrix in which almost every cell carries the maximum correlation weight is not a mapping but a declaration, since a course that contributes strongly to every programme outcome has no distinctive purpose, whereas a credible matrix is sparse and uneven, with many empty cells and a minority of strong ones. Second, evidence of review: a meaningful matrix is accompanied by attainment data computed against it, with target thresholds stated in advance and actual attainment recorded per CO and per PO, so that the matrix functions as an instrument of measurement rather than as a statement of aspiration. Third, and decisively, evidence of consequence: where attainment falls below target, the record should show what was changed, a revised assessment task, an added laboratory or field exercise, a remedial intervention, a re-sequenced module, and the subsequent cycle should show whether the change worked. A matrix accompanied by attainment data that never falls short, or by shortfalls that never produce action, has become a compliance ritual regardless of how carefully it was drawn. The underlying risk is one long recognised in curriculum theory: that curriculum design collapses into the specification of knowledge to be covered, displacing the engagement of the student that the specification was meant to serve (Barnett & Coate, 2005).

5. The Comparative Curricular Landscape across Public Universities

The focal public universities share the scaffolding mandated by NEP 2020 and the UGC framework, yet differ in pace of adoption, credit detail and institutional model. Because most are affiliating universities, each framework shapes botany and zoology education across a large network of government and aided colleges, typically through a common Faculty of Science that delivers both disciplines under the same credit rules. A region-wise account follows; analytical evaluation is reserved for Section 6.

5.1 Himachal Pradesh

Himachal Pradesh University (HPU), Shimla has aligned its large affiliated-college network with NEP, adopting the credit-based multidisciplinary structure and transitioning undergraduate courses to a full semester system; the Central University of Himachal Pradesh (Dharamshala) and Sardar Patel University (Mandi) deliver botany and zoology within the FYUGP framework as well. With much life-sciences teaching taking place in hill and rural colleges enjoying rich but logistically demanding access to Himalayan biodiversity, OBE here foregrounds field study, local biodiversity, medicinal plants, high-altitude and freshwater fauna, and conservation-oriented outcomes. Zoology outcomes commonly emphasise Himalayan entomology, cold-water fisheries, avifauna and wildlife observation.

5.2 Punjab and Chandigarh (UT)

Panjab University (PU), Chandigarh, a public university in the union territory serving colleges across Punjab and Chandigarh, has been an early, detailed adopter, maintaining a dedicated NEP curriculum portal and publishing discipline-wise NEP syllabi (including botany and zoology) with a general credit framework, operated partly through its Honours School system. Guru Nanak Dev University (GNDU), Amritsar has issued NEP templates and ordinances for its FYUGP with the standard three- and four-year exit ladder. Punjabi University, Patiala and the Central University of Punjab, Bathinda, the latter with a graduate-attributes-based, research- and entrepreneurship-oriented curriculum from 2021–22, complete a strong provincial ecosystem; Chandigarh's PU-affiliated government colleges follow the same science syllabi. Agrarian Punjab lends zoology curricula a distinct applied bent toward economic entomology, aquaculture and sericulture.

5.3 Haryana

Kurukshetra University (KU) was the first university in Haryana to move its undergraduate programmes onto the NEP structure, extending it to affiliated colleges from July 2023, and publishes NEP botany and zoology syllabi on the standard Major/Minor/Multidisciplinary/SEC/VAC structure. Its scheme of examination and syllabus for both subjects is issued under Multiple Entry-Exit, Internship and CBCS-LOCF in accordance with NEP-2020, with effect from 2023-24 in a phased manner. Direct examination of those two documents qualifies the state's apparent maturity in an instructive way. Both articulate Learning Outcomes (CLO) for every course, and the botany scheme states a separate starred outcome for the practical component of each paper, which is a genuine strength and one not matched by most institutions in this review. Neither document, however, contains any programme-level outcome tier: there is no Programme Outcome, Programme Specific Outcome or graduate-attribute statement in either scheme, and consequently no CO-PO mapping matrix. The cognitive level of the outcomes is also narrow, with 81 per cent of the zoology statements and 98 per cent of the botany statements resting on comprehension-level verbs such as understand, know, describe and recognise. Assessment weightings are stated explicitly and consistently, typically 20 internal to 50 end-term marks for a four-credit paper, but no attainment computation, target threshold or rubric appears. Maharshi Dayanand University (Rohtak), Chaudhary Devi Lal University (Sirsa) and the Central University of Haryana (Mahendergarh) operate comparable frameworks, giving the state a coordinated rollout across both disciplines; on the evidence of KU's own documents, however, that coordination is a matter of common course architecture rather than of a shared outcome-attainment apparatus.

5.4 Jammu & Kashmir

The University of Kashmir and the University of Jammu both operate the FYUGP, but the implementation dates commonly reported for the union territory require correction. Kashmir's framework rests on Notification No. F (UG Statutes-NEP-2020) Acad/KU/23 dated 4 August 2023, the 2023–24 session rather than 2022–23, with the Honours and Honours-with-Research provisions added only by Notification No. F (FYUGP-Honours/Research) Acad/KU/25 dated 9 September 2025. The statutes specify a full exit ladder (certificate after one year, diploma after two, a three-year Bachelor's degree, and a four-year Honours or Honours-with-Research degree), and gate the research mode at a CGPA of 7.5 across the first six semesters. Both disciplines are laid out across eight semesters on an identical three-course-per-semester pattern with a 12-credit dissertation in the final semester (BOT824RP in botany, ZOL822RP in zoology). At Jammu, the botany and zoology schemes are styled 'FYUP under CBCS as per NEP-2020' and are published semester-pair by semester-pair, the first pairs carrying examination years 2022–24.

Neither institution carries a programme-level outcome tier. Across the eighteen Jammu documents and the Kashmir statutes and both disciplinary frameworks there is no Programme Outcome, Programme-Specific Outcome or graduate-attribute statement, no CO–PO matrix, and no attainment, rubric or NHEQF vocabulary. What differs is the form in which course-level outcomes are written, and the difference matters more than it appears. Jammu states them as narrative paragraphs describing what a course will do rather than as enumerated statements of what a student will be able to do; because they are not indexed, they cannot be mapped or aggregated even in principle, which is a more fundamental obstacle to attainment measurement than a weak choice of verb. Kashmir encloses a single unenumerated 'Learning Outcome' sentence per botany course but gives zoology courses a properly enumerated bulleted set under a 'will be able to' stem, an asymmetry in the opposite direction to the one observed at Panjab and at Chaudhary Devi Lal University, and evidence that the two disciplines are documented to different standards within the same institution rather than according to any consistent disciplinary logic.

The regional anchoring the literature attributes to this union territory is real but narrower and more asymmetric than usually stated. In Jammu's zoology syllabi, named territorial content appears repeatedly at sub-unit level, the wildlife status of Jammu and Kashmir, its protected areas, its endemic animal species, wildlife tourism and ecotourism venues, and the status of parasitic diseases in India with special reference to Jammu and Kashmir. It sits, however, almost entirely in Multidisciplinary and Skill-Enhancement courses (Wildlife Biology, Wildlife: Conservation and Management, Medical Parasitology, Applied Zoology) rather than in the Major spine, so regional anchoring is genuine but peripheral to the disciplinary core. Botany carries effectively none: 'temperate, tropical, sub-tropical and alpine' is generic habitat classification, and the single territorial reference concerns funding schemes for mushroom cultivation. Of the regional features often ascribed to these syllabi, avian diversity is supported in the Jammu documents; distinctive alpine and temperate flora, high-altitude fauna and cold-water fisheries are not, the fisheries claim in particular finds no support at Jammu, where the terms do not occur, and a separately notified skill course in industrial fish and fisheries belongs to another subject board within the same faculty.

5.5 Uttarakhand

Hemvati Nandan Bahuguna Garhwal University (central; Srinagar-Garhwal) offers eight-semester FYUP B.Sc. programmes in botany and zoology under NEP, and Kumaun University (Nainital) has finalised its NEP B.Sc. syllabi through its Faculty of Science; Soban Singh Jeena University (Almora) and Doon University (Dehradun) operate within the state's common framework. As in Himachal Pradesh, the Himalayan setting foregrounds field-based, biodiversity- and conservation-oriented outcomes, with zoology drawing on montane entomology, herpetofauna, cold-water fish and wildlife study.

5.6 Rajasthan

The University of Rajasthan (Jaipur) has issued NEP semester-scheme B.Sc. botany and zoology syllabi, and Maharshi Dayanand Saraswati University (Ajmer), Mohanlal Sukhadia University (Udaipur), Jai Narain Vyas University (Jodhpur) and the Central University of Rajasthan deliver the disciplines within the same framework. Arid-zone syllabi often emphasise economic botany, xerophytic adaptation, arid-zone ecology and applied plant biotechnology in botany, and desert and reptilian adaptation, arid-zone entomology, apiculture and animal physiology of water conservation in zoology.

Two further Rajasthan schemes examined directly for this review sharpen the picture and show that a state-level generalisation cannot be sustained. Pandit Deendayal Upadhyaya Shekhawati University (Sikar) issues botany and zoology Major and Minor syllabi and a B.Sc. Certificate Programme structure under the heading 'PDUSU NEP Syllabus w.e.f. 2024-25'. Course-level outcomes are present and reasonably written, bulleted, action-verb led, and in places genuinely higher-order, as in 'evaluate in situ and ex-situ conservation strategies and interpret the Wildlife Protection Act (1972)' and 'apply knowledge of immunology to real-world contexts such as transfusion medicine, vaccine development, and disease diagnosis'. Above the course, however, there is nothing: no Programme Outcomes, no Programme-Specific Outcomes, no mapping matrix, and no Bloom, rubric or attainment vocabulary anywhere in the five documents. The certificate programme is the limiting case, carrying complete curriculum-structure tables, course code, title, lecture-tutorial-practical distribution, credits and a 10/20/70 continuous-work, mid-term and end-term weightage split, with no outcome statements at all. Marks architecture is fully specified; outcome architecture stops at the course.

Maharaja Ganga Singh University (Bikaner) is a counter-case on a different axis. Its B.Sc. botany scheme for session 2025-26 is still a Choice-Based Credit System document; NEP 2020 is invoked once, in a background narrative that pairs it with the UGC Quality Mandate for Higher Education Institutions-2021 and a 'Comprehensive Roadmap for Implementation of NEP', while FYUGP, NHEQF and LOCF are absent as named frameworks. No course in the scheme carries a course-outcome or course-objective heading; the only two occurrences of 'learning outcomes' are inside that background narrative, and the sole occurrence of 'mapping' is subject content, the linkage and mapping of genes. The background paragraph of this undergraduate document states that the university revised 'the curriculum of postgraduate programmes', which is postgraduate boilerplate carried unaltered into an undergraduate scheme and is direct textual evidence that reform language propagates by template rather than by re-derivation of outcomes at programme level. What the document does specify precisely is assessment: semester I comprises six credits and 150 marks, a four-credit theory paper worth 100 marks (80 external, 20 internal) and a two-credit laboratory course worth 50 (40 plus 10), with internal marks awarded on term tests, class tests, seminars, quizzes, chart or model preparation, plantation work and science-club activity, and a university-wide blended-learning consensus of ten per cent online delivery.

5.7 Delhi

The University of Delhi (DU) implemented its Undergraduate Curriculum Framework 2022 (UGCF), based on NEP, delivering botany and zoology as Discipline-Specific Courses within B.Sc. (Hons) Botany, B.Sc. (Hons) Zoology and B.Sc. (Hons) Life Sciences across four years with multiple entry/exit options and a 10-point grading system. Its syllabi were notified in stages by amendment to Ordinance V, semesters I and II in 2023, semesters IV to VI by notification of 6 October 2023, and semesters VII and VIII on 31 July 2025, and together they constitute the largest and most consistently specified body of course-level outcome documentation in this corpus. Every course carries a paired block of Learning Objectives and Learning Outcomes above a table of credit distribution (lecture, tutorial, practical/practice), eligibility criteria and pre-requisites, with practical hours stated exactly, as in 'Practical (30 hrs) (Laboratory periods: 15 classes of 2 hours each)'. Across roughly a thousand pages the corpus contains 488 objective blocks and 411 outcome blocks. Direct examination, however, corrects a claim this review and much of the surrounding literature had made about DU. There is no programme-level outcome tier: the terms Programme Outcome, Programme-Specific Outcome, PSO and graduate attribute do not occur anywhere in the corpus, there is no CO–PO or CO–PSO matrix, and Bloom's taxonomy, rubrics and attainment computation are equally absent, the apparent 'CO-PO' occurrence is 'co-pollutants' in an elective on e-waste, and every instance of 'mapping' is subject content such as gene, restriction or geological mapping. Nor do the botany and zoology syllabi document an internal-external marks split: 'CIA' does not occur in the corpus at all. The one outcome-assessment instrument DU does publish is the Semester VIII track guidance of January 2026, which assesses the research, project, translation and entrepreneurship tracks against verifiable deliverables, a report in prescribed format plus documented evidence of at least one scholarly outcome, together with viva-voce procedure. That is assessment of individual student work against stated requirements, not computation of programme-outcome attainment. Jamia Millia Islamia and Ambedkar University Delhi operate NEP-aligned frameworks as well, giving the capital an outcome-explicit model at course level across the plant and animal science.

5.8 Ladakh: an emerging case

Ladakh warrants separate treatment because it is the newest and least documented of the regions considered here, and because its inclusion completes the environmental gradient on which the framework proposed in Section 11 turns. The University of Ladakh describes itself as established in 2019 and as the only trans-Himalayan institute of higher learning and research in India, with headquarters at both Leh and Kargil and nine or more constituent and affiliated colleges (University of Ladakh, 2026). Botany, Zoology and Life Science are listed as departments at both the Leh and Kargil campuses, and the university's published programme counts, fifteen undergraduate, fifty postgraduate and six doctoral programmes, indicate a system whose weight still sits at postgraduate level, so undergraduate botany and zoology in Ladakh are delivered through a combination of campus departments and the constituent and affiliated college network. The university's own pages link a Board of Studies document for the Four-Year Undergraduate Programme under NEP 2020, which establishes that Ladakh has formally adopted the FYUGP structure; the document is hosted on a subdomain that was unreachable throughout the period of this review, so its contents could not be examined.

The consequence for this review must be stated plainly. Unlike the other regions in this section, no undergraduate botany or zoology curricular document for Ladakh could be obtained: the university's site links a Board of Studies document for the FYUGP but hosts it on a subdomain that did not respond, and publishes no botany or zoology syllabus elsewhere, and the region is therefore the one case in Table 3 that rests on institutional and secondary sources rather than on a primary curricular document analysed directly. Nothing is claimed here about Ladakh's course outcomes, its CO-PO mapping practice or its attainment procedures, and the region is deliberately excluded from the comparative ratings in Table 4 for that reason. What can be said is structural: as a system whose undergraduate provision runs largely through constituent and affiliated colleges under a university founded in 2019, Ladakh is implementing outcome-based undergraduate provision without the legacy of a pre-NEP departmental curriculum to convert, and is at an earlier stage of that implementation than any other institution considered here.

Its curricular significance is nonetheless disproportionate to its size. Ladakh's cold-desert and trans-Himalayan systems, its high-altitude flora, its pastoral and agro-pastoral land use and its cold-adapted fauna constitute a biogeographic setting that none of the other seven regions can supply, and the university's establishment of a Centre for Himalayan and Trans-Himalayan Studies alongside its botany and zoology departments indicates the kind of regional anchoring that pillar 1 of the ILS-OBE framework requires. The framework's central claim, that regional biodiversity should be the axis of outcome design rather than an illustration appended to it, is most clearly tested where the biota is most distinctive. Ladakh is therefore included here as a prospective rather than an evidenced case: an emerging system whose curricular documents, when published, will provide the sharpest available test of whether the regional-anchoring principle is being applied in practice or merely endorsed in prospectuses.

Table 3 consolidates the institutional landscape described in this section, listing the representative public universities in each state and union territory that deliver undergraduate botany and zoology under the NEP framework, together with the programme structure each has adopted.

Table 3. Representative public universities delivering NEP-2020 undergraduate botany and zoology across the nine focal states/UTs. Lists are illustrative, not exhaustive.

State / UT	Representative public universities offering NEP-2020 botany and zoology at UG level	NEP UG rollout
Himachal Pradesh	Himachal Pradesh University (Shimla); Central University of Himachal Pradesh (Dharamshala); Sardar Patel University (Mandi)	Semester/credit system; Himalayan flora & fauna field focus
Punjab	Panjab University (Chandigarh); Guru Nanak Dev University (Amritsar); Punjabi University (Patiala); Central University of Punjab (Bathinda)	Early adopters; Honours School; 2021–24; economic entomology & aquaculture emphasis
Chandigarh (UT)	Panjab University, Chandigarh; PU-affiliated government colleges (e.g., PGGC-11)	Dedicated NEP science portal
Haryana	Kurukshetra University; Maharshi Dayanand University (Rohtak); Ch. Devi Lal University (Sirsa); Central University of Haryana (Mahendergarh)	First in state; CBCS-LOCF scheme w.e.f. 2023-24 (phased); colleges 2023
Jammu & Kashmir	University of Jammu; University of Kashmir; Cluster University of Jammu; Central Universities of Jammu / Kashmir	Kashmir: UG Statutes notified 04-08-2023; Honours/Research added 09-09-2025. Jammu: FYUP under CBCS, exam years from 2022–24. Regional fauna named in MDC/SEC courses, not the Major spine
Uttarakhand	H.N.B. Garhwal University (Central); Kumaun University (Nainital); Soban Singh Jeena University (Almora); Doon University	Eight-semester FYUP; common state framework; montane biodiversity
Rajasthan	University of Rajasthan (Jaipur); MDS University (Ajmer); Mohanlal Sukhadia University (Udaipur); Jai Narain Vyas University (Jodhpur); Central University of Rajasthan; Pandit Deendayal Upadhyaya Shekhawati University (Sikar); Maharaja Ganga Singh University (Bikaner)	Mixed: NEP semester schemes (PDUSU w.e.f. 2024-25) alongside CBCS schemes still current in 2025-26 (MGSU); arid-zone flora & desert fauna emphasis
Delhi	University of Delhi (UGCF 2022); Jamia Millia Islamia; Ambedkar University Delhi	UGCF 2022; DSC-based, PO-explicit; Hons Botany/Zoology/Life Sciences
Ladakh	University of Ladakh (Leh & Kargil campuses; constituent Government Degree Colleges)	Emerging; UG delivered through constituent colleges; cold-desert & trans-Himalayan biota; no syllabus published, not directly verified

6. Comparative Analysis: Why They Differ and What Works Best

Description invites the analytical questions that a review must answer: why do these curricula differ, and where does each system's comparative strength lie? Three forces explain the variation atop a common national template. First, institutional type: research-intensive and centrally funded universities resource laboratories better and embed research earlier than teaching-oriented state universities with large affiliated networks, the University of Delhi specifies outcomes for every course, and Jamia Millia Islamia has built the most precisely specified four-year structure in this corpus, with five award levels at exact credit thresholds and a 12-credit research route. Institutional type does not, however, predict outcome articulation. Jamia's 46-page B.Sc. Biosciences framework contains not one outcome or objective statement, and no institution of any type publishes a programme-outcome tier for these disciplines (Section 6).

Structural capacity and outcome substance vary independently. Second, geography and biota: Himalayan universities (HPU, HNB Garhwal, Jammu, Kashmir) build outcomes around alpine and temperate biodiversity, cold-water fauna and field study, while arid-zone universities (Rajasthan) foreground xerophytes, economic botany, desert fauna and arid-zone ecology, an ecological division of pedagogical labour that operates in both botany and zoology. Third, adoption timing and administrative capacity: early, well-documented adopters (Panjab University, Kurukshetra University, University of Delhi) publish fuller and more internally consistent curricular documentation than institutions still migrating from annual to semester systems, one of which (Maharaja Ganga Singh University) is still issuing a Choice-Based Credit System scheme for 2025-26. That advantage is in documentation, not in mapping apparatus, which none of them has.

On this basis the following analytical judgements can be offered, framed as reasoned assessments from public curricular documentation rather than definitive rankings. Course-level outcome writing is most systematic at the University of Delhi, where every course pairs a block of Learning Objectives with a block of Learning Outcomes in a standard format across roughly a thousand pages; several state-university documents still mix genuine outcomes with restated content, and two institutions in the corpus use outcome and objective vocabulary in different disciplines of the same faculty. It should be recorded, however, that no document examined for this review invokes Bloom's revised taxonomy by name, so the alignment between outcome verbs and cognitive levels described in Section 4 is an analytical reconstruction rather than a stated design principle of any of these curricula. Practical and field training is strongest in the Himalayan universities, HPU, HNB Garhwal, and the Universities of Jammu and Kashmir, whose syllabi mandate multi-day field study and biodiversity documentation and whose settings supply exceptional living material for both plant and animal study. In zoology specifically, the stronger systems have converted the post-dissection transition into an opportunity, replacing routine dissection with museum study, permanent slides, models, simulated dissection and structured field observation rather than simply subtracting content (UGC, 2014; Akbarsha, 2007). Assessment documentation is most complete where marks architecture is fully specified, the Rajasthan schemes state internal and external weightages explicitly, and Delhi specifies credit distribution and practical hours precisely, but this must be distinguished from attainment maturity, which is low everywhere: not one document in the corpus computes outcome attainment, states a target threshold, or publishes a rubric, and the words 'attainment' and 'rubric' as assessment apparatus are absent from all of them. CO–PO mapping is the dimension on which the corpus is weakest, and the weakness is more general than the literature suggests and more general than an earlier draft of this review supposed. Not one of the institutions examined directly publishes a CO–PO or CO–PSO matrix for undergraduate botany or zoology. This includes the two systems most often cited as exemplars: the University of Delhi's UGCF corpus contains no programme-outcome tier whatever, and Panjab University publishes Programme and Programme-Specific Outcomes for zoology yet still no matrix linking them to course outcomes, while its botany syllabus uses objective language exclusively. The sole genuine mapping matrix located in the entire corpus, a CO–PSO grid with a defined 1–3 correlation scale, sits in Kurukshetra University's university-wide outcomes compendium under a postgraduate humanities programme, presented explicitly as a worked illustration of method for a hypothetical course. Several documents contain the word 'mapping', but in every case it is subject content: the linkage and mapping of genes, restriction mapping, QTL mapping or geological mapping. Counting such tokens as evidence of curricular alignment would materially overstate adoption. Overall NEP/FYUGP alignment, the coherent integration of Major, Minor, Multidisciplinary, SEC, VAC, internship and research tracks with an outcome spine, is most complete at the University of Delhi and Panjab University, strong at GNDU, Kurukshetra and Kashmir, and still consolidating elsewhere. Table 4 renders these indicative assessments in a comparative matrix.

Table 4. Indicative comparative rating of public-university life-sciences (botany and zoology) systems (Strong / Moderate / Developing / Absent).

University / system	CO articulation	Practical & field	Assessment & attainment	CO–PO mapping	NEP/FYUGP alignment
University of Delhi (UGCF)	Strong (objectives + outcomes paired for every course)	Moderate	Developing (credit/practical hours precise; no CIA–SEE split, no attainment computation)	Absent (no PO/PSO tier)	Strong
Panjab University	Moderate (zoology outcome-led with PO/PSO; botany objective-led)	Moderate	Developing	Absent (PO/PSO published, no matrix)	Strong

Central universities (Jamia Millia Islamia)	Absent (JMI: 0 outcome or objective statements in 46 pp)	Developing (practical credit without specified content)	Developing	Absent	Strong
Guru Nanak Dev University	Moderate	Moderate	Developing	Absent	Strong
Kurukshetra University	Moderate	Moderate	Developing	Absent (matrix exists only under a PG humanities programme)	Strong
HPU / HNB Garhwal (Himalayan)	Moderate	Strong	Developing	Absent	Moderate
University of Kashmir	Moderate (enumerated in zoology; single sentence in botany)	Strong	Developing	Absent	Strong (FYUGP statutes, exit ladder, 12-cr dissertation)
University of Jammu	Weak (narrative paragraphs, not enumerated)	Strong	Developing	Absent	Moderate (FYUP under CBCS)
University of Rajasthan	Moderate	Moderate	Developing	Absent	Moderate
PDUS Shekhawati University	Moderate (bulleted, some higher-order)	Moderate	Developing (marks split specified)	Absent	Moderate (NEP-styled, not FYUGP)
Maharaja Ganga Singh University	Absent	Moderate (dissection retained as mark head)	Developing (marks fully specified)	Absent	Weak (CBCS; NEP narrative only)

The pattern is instructive, and it is not the pattern the literature predicts. No single system dominates every dimension: the University of Delhi leads on the volume and consistency of course-level outcome specification, the Himalayan universities lead on the experiential and field competencies that are the life sciences' distinctive contribution, and the Rajasthan schemes are the most explicit about marks architecture. But on the two dimensions that distinguish outcome-based education from a well-documented syllabus, a programme-outcome tier with a mapping matrix, and computed attainment feeding a revision loop, no institution in this corpus leads, because none has either. The strongest available model is therefore a composite of documented practice: Delhi-grade outcome specification, Himalayan-grade field training, Rajasthan-grade transparency about assessment weightings, and the mapping and attainment apparatus that would have to be built from the accreditation literature rather than borrowed from any university examined here. That absence, rather than any ranking among these institutions, motivates the integrative framework proposed in Section 11.

7. Evidence Synthesis: Strengths, Weaknesses, Trends and Open Issues

Read across the nine regions and both disciplines, the evidence yields consistent cross-cutting patterns rather than isolated institutional stories.

Common strengths. A shared outcome vocabulary (Graduate Attributes → PO → PSO → CO) now exists everywhere and applies uniformly to botany and zoology; the FYUGP credit skeleton and multiple entry/exit ladder are universally adopted; skill-enhancement and value-added courses have injected genuine vocational and entrepreneurial content in both plant and animal sciences; practical work and field study remain compulsory and, in the hill states, exceptionally rich; and internship/research components have created, for the first time at scale, authentic experiential learning within the degree. In zoology, the reconfiguration of practicals away from routine dissection has, in the better cases, strengthened observation-, model- and field-based learning and made animal-welfare ethics an explicit part of the curriculum.

Recurring weaknesses. Faculty capacity for writing measurable outcomes and computing attainment is uneven; and for undergraduate botany and zoology in this corpus the mapping and attainment apparatus is not weakly used but wholly absent from the published curricula, so the audit-versus-diagnosis question described in the accreditation literature does not yet arise at this level; continuous internal assessment varies widely and can inflate marks; laboratory, greenhouse, herbarium, museum, aquarium and field infrastructure is unevenly resourced across affiliated colleges; and indirect-attainment evidence (graduate and employer feedback) is often perfunctory, hollowing out the improvement loop that is the point of OBE (NBA, 2013; Rao, 2020). A zoology-specific weakness is that the withdrawal of dissection has not always been matched by investment in adequate replacements, models, museum specimens, virtual-dissection software and structured field protocols, so that in poorly resourced colleges the psychomotor and structural-anatomy outcomes it once served risk being thinned rather than re-based.

Emerging trends. Several developments are visible: growing use of blended and ICT-enabled learning, virtual laboratories, virtual dissection, digital herbaria and digital museums/e-fauna resources (de Jong, Linn & Zacharia, 2013; Brinson, 2015; Garrison & Kanuka, 2004); adoption of SWAYAM/MOOC credits; a rise in research-embedded honours tracks; increasing rubric-based practical assessment; and a slow professionalisation of attainment analytics through OBE software. Regionally distinctive curricula, Himalayan biodiversity, arid-zone economic botany and desert fauna, are being deliberately cultivated as signature strengths, and animal-welfare and conservation ethics are being formalised as graduate attributes.

Unresolved issues. Four tensions remain open across both disciplines: the trade-off between multidisciplinary breadth and disciplinary depth (systematics, physiology and laboratory/field craft); the reconciliation of standardized affiliating-university examinations with authentic, outcome-tagged assessment; the gap between syllabus ambition and infrastructural reality, acute for zoology where credible dissection replacements are unevenly available; and the still-weak link between declared employability outcomes and measured graduate destinations (Yorke, 2006; Jackson, 2015). Table 5 consolidates the synthesis.

Table 5. Evidence synthesis of common strengths and recurring weaknesses across the focal public universities (botany and zoology).

Dimension	Common strengths	Recurring weaknesses
Curriculum structure	Universal FYUGP credit skeleton; multiple entry/exit; flexible Major–Minor–MDC baskets across botany & zoology	Timetabling/advising overload; breadth can dilute core botany/zoology
Outcome articulation	Shared GA→PO→PSO→CO vocabulary; Bloom-based verbs for both disciplines	Outcomes sometimes restate content; quality uneven across colleges
Practical & field training	Compulsory practicals every semester; rich field study, herbaria & museums; humane, model/virtual zoology practicals	Infrastructure uneven; field logistics/funding constrained; dissection replacements not always resourced
Pedagogy	Endorsement of inquiry, experiential, blended & virtual-dissection methods	Lecture-transmission persists; large classes; guest-faculty load
Assessment & attainment	Documented CIA–SEE split; project/viva; rubrics emerging; observation-based zoology assessment	CIA inflation; tokenistic mapping; weak indirect attainment
Skills & employability	SEC/VAC vocational content (mushroom, sericulture, apiculture, aquaculture, etc.); mandatory internship	Weak industry linkage; destinations rarely measured
Digital & QA	Growing virtual labs, virtual dissection, digital herbaria & museums, SWAYAM, OBE software	Digital divide; CQI loops often nominal

8. Skill Development, Employability and Practical Training

8.1 Skill-enhancement and value-added pathways

A defining ambition of NEP 2020 is to dissolve the historic separation between "academic" and "vocational" learning, and life-sciences curricula carry several vehicles for this. Skill Enhancement Courses (SECs) convert biological knowledge into marketable competence. In botany these include mushroom cultivation, nursery and gardening, floriculture and landscaping, biofertiliser and biopesticide production, medicinal and aromatic plant cultivation, tissue-culture technique, seed technology and food preservation. In zoology they include sericulture, apiculture (bee-keeping), aquaculture and ornamental fish-keeping, poultry and dairy management, vermicomposting (shared with botany), lac culture, medical and veterinary entomology, and pest management. Together with Value-Added and Ability Enhancement Courses that add environmental literacy, bioethics and animal-welfare awareness, communication and digital skills, these broaden employability and align with NEP's emphasis on entrepreneurship and self-employment (Yorke, 2006; Knight & Yorke, 2003; Bridgstock, 2009).

8.2 Practical training in botany and zoology

Practical training is the heart of life-sciences OBE, since laboratory and field work develop the psychomotor and higher-order outcomes that lectures cannot (Sundberg & Moncada, 1994; Hofstein & Lunetta, 2004; Feisel & Rosa, 2005). In botany, compulsory laboratory work in every semester builds microscopy, micrometry, hand-sectioning, staining, mounting, permanent-slide and museum preparation, identification and dissection of plant material; herbarium preparation trains collection, pressing, mounting, accessioning and taxonomic documentation, cultivating both precision and conservation ethics. In zoology, practicals build microscopy and histological technique, permanent-slide and museum-specimen study, mounting and identification, comparative-anatomy interpretation, and animal physiology and ecology exercises. Crucially, following the UGC's restriction of animal dissection (UGC, 2014; Akbarsha, 2007), zoology practicals increasingly rely on museum specimens, models, charts, virtual-dissection software and non-invasive field observation rather than the routine killing and dissection of animals such as frogs, earthworms and fish, a shift with both ethical and biodiversity-conservation rationales, given documented pressure on species collected for teaching. Field study and study tours, of several days each year with a required minimum, generate authentic outcomes in survey design, record-keeping, biodiversity assessment and animal behaviour observation (AAAS, 2011). This component is especially rich in the Himalayan states, while Rajasthan builds comparable strengths around xerophytic and economic flora and desert fauna.

8.3 Internships, experiential learning and the research track

The internship and experiential-learning component, creditised within the FYUGP, is a decisive addition (Kolb, 1984; Jackson, 2015). Students undertake defined projects, in botany, cultivation of medicinal or fruit plants, mushroom production, studies of campus or regional flora, herbarium arrangement, river restoration and People's Biodiversity Register preparation; in zoology, sericulture and apiculture units, aquaculture and ornamental-fish rearing, vermicomposting, faunal and avian surveys, insect and museum collection curation, and wildlife or wetland monitoring, keeping a log book and defending a report by viva voce. Where placements connect to nurseries, botanical gardens, agricultural stations, fisheries and animal-husbandry departments, sericulture and apiculture units, zoos and wildlife sanctuaries, biotechnology laboratories and environmental NGOs, they build the networks and applied confidence that translate into employability. The fourth-year research track, well developed at DU and the central universities, extends this into a supervised project with literature review, design, analysis and defence, the strongest single instrument for attaining the higher-order create-level outcomes of the programme (Wood, 2009).

8.4 The evidence base for employability claims

The employability rationale for these components is explicit in policy, but the evidence base against which it should be judged is thinner than the policy language implies, and it is thin in a particular direction. Indian research on graduate employability is substantial but concentrated overwhelmingly in engineering, technical and vocational education. Large-sample employer and graduate surveys in that sector have documented a persistent gap between the attributes employers require and those that degree programmes deliver, with core employability skills, communication, analytical reasoning, teamwork and the ability to apply knowledge to unfamiliar problems, rated as more deficient than discipline-specific technical knowledge (Gokuladas, 2010; Blom & Saeki, 2011). Analyses at the level of the higher-education system reach the same conclusion and locate the cause in curricular design rather than in graduate numbers: expansion of enrolment has not been matched by improvement in the employability of those enrolled, and skill gaps persist across qualification levels (Khare, 2014; Unni, 2016). Studies of vocational and skills provision similarly find that formal training credentials translate into labour-market advantage unevenly, and that the quality of practical exposure matters more than its nominal presence in the curriculum (Agrawal, 2012). Read together, these findings support the design logic of SECs, internships and the research track, they target precisely the applied and transferable attributes the literature identifies as deficient, while also warning that a course basket bearing an employability label does not by itself generate employability.

For the life sciences specifically, however, no comparable evidence exists. We are not aware of any published graduate-destination or tracer study of Indian undergraduate botany or zoology cohorts, and none of the focal universities publishes destination data for its life-sciences graduates. This is a significant limitation of the present review and of the field: the employability claims made for SECs and internships in life-sciences curricula are at present arguments from curricular design rather than findings from outcome measurement, and this review can assess only the former. Closing the gap requires the kind of evidence that is routinely collected elsewhere, systematic tracer studies following botany and zoology cohorts at fixed intervals after graduation, recording progression to postgraduate study, entry to research, teaching, environmental and conservation practice, agricultural and pharmaceutical employment, public-sector examination outcomes and self-employment, and linking these destinations back to the specific SEC, internship and project components each graduate completed. Such data would allow the attainment cycle described in Section 10 to be closed at the programme level rather than the course level, and would convert graduate outcomes from a declared aspiration in the outcome architecture into a measured one. We recommend it as the highest-priority direction for empirical research following from this review, and note that the digitised OBE record-keeping recommended in Section 13 is a precondition for it, since destination data are analytically useful only when they can be joined to individual curricular histories.

8.5 Reconfiguring zoology practical outcomes after dissection reform

The restriction of animal dissection is the single largest change to life-sciences practical work in the NEP era, and because it is often reported as a subtraction it deserves explicit treatment as a reconfiguration of outcomes.

What was removed. Following sustained advocacy and the University Grants Commission's guidance on discontinuing dissection and animal experimentation in zoology and life-sciences programmes (Akbarsha, 2007; UGC, 2014), the routine dissection of animals for demonstration purposes has been withdrawn from undergraduate practical schedules. In the traditional syllabus this meant the dissection of the frog, earthworm, cockroach, freshwater mussel, prawn and teleost fish for the study of digestive, nervous, circulatory, reproductive and respiratory systems, together with mounting exercises requiring freshly killed material and in vivo physiology experiments on live animals. The rationale was twofold: an ethical objection to the killing of animals where a non-lethal alternative achieves the same instructional purpose, and a conservation concern, since collection for teaching had exerted documented pressure on locally abundant species harvested in large numbers each session.

What has replaced it. The replacement provision, where it has been implemented seriously, has five components: curated museum specimens and preserved material, which allow morphological and comparative-anatomical study to continue without new killing; permanent slides, whole mounts and prepared histological series, which preserve microscopy, micrometry and histological-interpretation skills intact; anatomical models, charts and three-dimensional printed structures used for systems anatomy; virtual-dissection and computer-based simulation software, which permits repeated, reversible exploration of anatomical relationships and physiological processes that a single specimen allows only once; and, most significantly for outcome quality, an expansion of non-invasive field and behavioural work, including ethogram-based behavioural observation, faunal and avian survey, freshwater invertebrate sampling, and the study of live animals in natural or semi-natural settings. In the strongest systems this last component is not an adjunct but the centre of gravity of the practical curriculum, and the evidence on virtual and remote laboratory provision suggests that carefully designed simulation achieves learning outcomes comparable to hands-on work for conceptual and analytical objectives, while remaining a weaker substitute for manipulative skill (de Jong et al., 2013; Brinson, 2015).

The pattern is confirmed by the two Haryana schemes examined directly for this review. Kurukshetra University's NEP zoology syllabus retains the full traditional range of type-study animals but teaches their internal anatomy entirely without dissection: the practical schedule prescribes computer-simulated study or models of the digestive, reproductive and nervous systems of Earthworm, the pallial complex and digestive and nervous systems of Pila, the general anatomy of Herdmania, the digestive, arterial, venous and urinogenital systems of Rat and the corresponding systems of Hemidactylus, with cockroach anatomy shown by demonstration. No student dissection appears anywhere in the scheme. This is the second instance in the present corpus of complete replacement rather than partial restriction, and the only one that names computer simulation as the designated substitute for specific type-study animals rather than referring generically to simulations, charts or models. It is worth noting what the substitution does and does not preserve: the comparative-anatomical content survives intact, and the range of taxa is if anything wider than a dissection-based schedule could sustain, but the psychomotor outcomes of the original exercise, fine instrument control, tissue-plane recognition by touch and the discipline of working from a specimen rather than a representation, have no substitute in the prescribed schedule and are simply absent from the stated outcomes.

Three schemes examined directly for this review show that 'replacement' is not one practice but several, distributed along a spectrum, and that where a university sits on that spectrum is invisible from its outcome statements. Kurukshetra University occupies one pole: the full traditional range of type-study animals is retained and their internal anatomy is taught entirely by computer simulation or models, with no student dissection anywhere in the scheme. Pandit Deendayal Upadhyaya Shekhawati University occupies a second position with no digital component at all. Its vertebrate practical course instructs that permanent preparations of Herdmania spicules and pharyngeal wall, fish scales and striped muscle fibres be studied 'with the help of Chart and Model'; comparative anatomy proceeds through osteology of articulated and disarticulated skeletons of frog, Varanus, fowl and rabbit, a prescribed series of microscopic slides and whole mounts, and a museum-specimen list running to some forty taxa from Ascidia and Ammocoete through Torpedo, Protopterus and Axolotl to Naja and Bungarus. Neither 'simulation' nor 'virtual' appears anywhere in its five documents, and the only occurrence of 'dissect' is the dissecting microscope. What survives as genuine psychomotor work is microtechnique: narcotisation, fixing, preservation, washing, staining, destaining, dehydration, clearing, dealcoholisation and mounting, with named fixatives and stains, alongside a physiology and biochemistry practicum that retains ABO grouping, haemocytometry, Sahli haemoglobinometry, haemin crystal preparation, sphygmomanometry, transaminase and phosphatase assays and thin-layer chromatography of amino acids. The University of Jammu's honours semesters follow the same logic in a third variant, delivering the complete phylum sequence through museum specimens, charts and photographs while retaining the preparation of permanent stained mounts, Obelia, the parapodium of Nereis, the nephridium and ovary of the earthworm, the statocyst of the prawn, the mouthparts and trachea of the cockroach, and mandating a visit to the departmental Zoological Museum and Butterfly Park; virtual laboratories are cited by URL, but only within the molecular-biology practicum and not for anatomy at all.

Against these, Maharaja Ganga Singh University shows that the reform is not universal. Its zoology practical scheme retains 'Dissection' as a named, separately weighted mark head, eight marks of forty in the first semester, alongside culture, preparation, spots, record and viva voce, and elsewhere prints the head as 'Dissection/demonstration' with models, charts and computer simulation offered parenthetically as alternatives for the same material. The choice between cutting an animal and simulating it is thereby devolved to the department and to the examiner's discretion, and is not resolved at curriculum level at all. For an outcome-based reading this is the least tractable of the four arrangements: two students sitting the same examination for the same eight marks may have developed entirely different psychomotor capabilities, and no outcome statement in the document distinguishes them.

How the substitutes align with OBE outcomes. Read against the outcome domains, the transition is neither a straightforward loss nor a costless gain, and the three domains behave differently. In the psychomotor domain some outcomes are genuinely displaced, the fine manipulative control, instrument handling and tissue-plane judgement developed by dissection have no exact equivalent, while others are preserved or strengthened, since microtomy, staining, mounting, permanent-slide and museum-specimen preparation, micrometry and field-sampling technique all remain and can absorb the freed laboratory hours. In the cognitive and observational domain the change is largely favourable: comparative anatomy assessed from curated museum series and prepared slides can be examined more consistently than from variable student dissections; virtual dissection permits repetition and self-correction that a single specimen precludes; and structured field observation develops survey design, systematic recording, quantitative estimation and inference from behavioural data, which are higher-order outcomes that routine dissection did not address. In the affective and ethical domain the transition is an unambiguous gain, and one that the outcome architecture can capture directly: students encounter animal-welfare reasoning, the ethics of specimen collection and conservation-minded practice as operative constraints on their own laboratory conduct rather than as topics in a bioethics lecture, which is precisely the shift from knowing about a value to acting on it that the affective taxonomy describes (Krathwohl, Bloom & Masia, 1964).

Two risks attend the transition, and both are matters of implementation rather than of principle. The first is substitution in name only: where dissection is removed but museum collections are not curated, slides not renewed, models not purchased and virtual-dissection licences not acquired, practical hours contract into demonstration and the psychomotor domain is depleted without compensation. The second is the inverse of the first, the assumption that software can carry the whole load, when the evidence indicates that simulation complements rather than replaces physical laboratory and field work (de Jong et al., 2013). The outcome-based response to both is the same: practical course outcomes should be rewritten to state what the student will be able to do under the new provision, and attainment should be measured against those revised statements, so that the adequacy of the replacement becomes visible in attainment data rather than assumed from the syllabus.

9. Effective Teaching-Learning Strategies

OBE is only as good as the pedagogy that delivers it (Barr & Tagg, 1995; Ramsden, 2003). Declared outcomes attain nothing unless teaching-learning activities are chosen to produce them, and the evidence base for active, learner-centred methods in science is now substantial, extending from early advocacy for active engagement in the conventional classroom to meta-analytic confirmation of its effect on attainment (Bonwell & Eison, 1991; Ebert-May, Brewer & Allred, 1997; Prince, 2004; Michael, 2006; Deslauriers, Schelew & Wieman, 2011; Freeman et al., 2014). NEP-aligned botany and zoology syllabi endorse a repertoire that can be matched to the cognitive level of each outcome.

- Discovery- and inquiry-based learning, students investigate real specimens, datasets and field problems rather than receiving pre-digested conclusions (Bruner, 1961; NRC, 2000; Minner, Levy & Century, 2010), developing the analytical and evaluative outcomes of both plant and animal biology; guidance must be adequate to avoid the pitfalls of minimally guided instruction (Kirschner, Sweller & Clark, 2006).
- Experiential and problem-based learning, laboratory investigation, floristic and faunal field surveys, internships and mini-projects place students in the role of practising botanists and zoologists (Dewey, 1938; Kolb, 1984; Hmelo-Silver, 2004; Prince & Felder, 2006), directly serving psychomotor and higher-order cognitive outcomes.
- Blended and ICT-enabled learning, flipped classrooms, e-learning modules, virtual laboratories and dissection simulations, SWAYAM/MOOC integration, and digital herbaria, digital museums and plant and animal databases (Garrison & Kanuka, 2004; Bishop & Verleger, 2013; de Jong et al., 2013; Means et al., 2013). Virtual dissection is particularly valuable in zoology, where it both replaces routine animal use and supports repeatable, annotated study of anatomy, and it is a lifeline for hill and rural colleges with constrained laboratories.
- Collaborative and peer learning, group projects, seminars, debates and peer review (Vygotsky, 1978) build communication and teamwork while deepening understanding through articulation.
- Case-based and scientific-teaching approaches, crop-failure diagnostics, conservation dilemmas, ethnobotanical and ethnozoological documentation, economic-botany and economic-zoology cases, pest and vector-borne-disease scenarios, and animal-welfare debates (Handelsman et al., 2004; Tanner & Allen, 2004) contextualise the life sciences within real societal, economic and ethical problems, while directly confronting plant blindness and the neglect of invertebrate and non-charismatic animal diversity (Wandersee & Schussler, 2001; Krosnick, Baker & Moore, 2018; Stagg & Verde, 2019).

Because these methods are frequently endorsed in the abstract and implemented unevenly in practice, it is worth stating concretely what each looks like in the two disciplines, since the same method serves different competencies depending on the organism studied. In inquiry-based learning, a botany class investigates the effect of a controlled variable on seed germination, temperature, light quality, salinity or a growth regulator, with students formulating the hypothesis, designing the treatment array, scoring germination percentage and rate over time, and defending the inference against alternative explanations; the zoology equivalent is a behavioural observation protocol in which students construct an ethogram for an accessible taxon, sample behaviour by scan or focal-animal method at fixed intervals, and test a stated prediction about activity budget or habitat use against their own data.

Both develop hypothesis formulation, systematic recording and evidence-based inference, but the botanical version foregrounds controlled experimentation and the zoological one foregrounds observational sampling design and inter-observer reliability. In experiential and field-based learning, botany students conduct a quadrat-based floristic survey of a campus or reserve site, computing frequency, density and abundance, preparing herbarium sheets with correct collection data, and identifying material to species using regional floras and keys; zoology students conduct a faunal survey using methods appropriate to the group, line transect and point count for birds, kick-net sampling for freshwater invertebrates, pitfall trapping for ground arthropods, recording, identifying and releasing live material, so that the psychomotor outcome is sampling and handling technique rather than dissection. In case-based learning, a botany case might present a crop-failure diagnosis in which students must distinguish nutrient deficiency, pathogen and abiotic stress from symptom evidence, or an ethnobotanical documentation exercise linking local plant use to phytochemistry and intellectual-property questions; a zoology case might present a human–wildlife conflict or vector-borne disease scenario requiring students to weigh ecological, public-health and welfare considerations against one another. In blended and ICT-enabled learning, the botanical application is dominated by digital herbaria, online floras and image-based identification resources that give students access to reference material their own institution cannot hold, while the zoological application centres on virtual dissection and physiology simulation, which substitute for animal use rather than supplementing a collection. The pattern across all four is consistent: botany's practical outcomes are built primarily on controlled experimentation and collection-based systematics, zoology's on non-invasive observation, prepared and curated material, and behavioural sampling, and course outcomes should be written to reflect that difference rather than in generic terms that apply to neither.

Effective practice matches method to outcome level: lectures, demonstrations and reading build remember- and understand-level outcomes; laboratory, field and problem-based work develop apply and analyse; and independent projects, research and design tasks reach evaluate and create (Anderson & Krathwohl, 2001; Killen, 2007; Crowe et al., 2008). The teacher's role shifts from lecturer to designer, demonstrator, facilitator and certifier of learning. Constructive alignment keeps the repertoire honest: every activity should be traceable to a course outcome, and every outcome served by an activity capable of producing it (Biggs & Tang, 2011).

10. Assessment and Outcome-Attainment Measurement

Assessment in OBE is not an end-point verdict but the evidentiary system through which attainment is judged and improved (Black & Wiliam, 1998; Sadler, 1989; Boud & Falchikov, 2006). NEP-aligned botany and zoology programmes combine Continuous Internal Assessment (CIA), formative, spread across the semester, with a summative End-Semester Examination (SEE) for theory and practical courses, supplemented by project and viva-voce evaluation. The formative component draws on assignments, tests, presentations, seminars, literature review, laboratory records and field reports; well-designed formative assessment with timely feedback is among the most powerful levers on learning (Nicol & Macfarlane-Dick, 2006; Gibbs & Simpson, 2004; Wiliam, 2011).

Practical assessment in the life sciences is unusually authentic because it evaluates skills directly (Brown, Bull & Pendlebury, 1997). Representative schemes weight the laboratory record for scientific accuracy, completeness, neatness and legibility, and assess field reports, prepared slides, herbarium submissions and, in zoology, museum-specimen identification, permanent slides and comparative-anatomy interpretation, alongside spot identification and experiment performance; rubrics make such judgements transparent and reproducible (Andrade, 2000). Because zoology no longer relies on live dissection for much of its practical work, assessment increasingly rewards observation, identification, interpretation of prepared and virtual material, and field and behavioural documentation, competencies that align well with higher-order outcomes and with humane practice. Project and general viva-voce components assess the ability to define a problem, review literature, design and execute investigation, analyse data and defend conclusions, evidence of the highest-order outcomes that written examinations cannot capture, and a design that aligns assessment with long-term learning (Boud & Falchikov, 2006).

The distinctive machinery of OBE is attainment measurement (NBA, 2013; Rao, 2020). Assessment tasks are tagged to the COs they test; performance is aggregated against each CO; and CO attainment is computed as a combination of direct attainment (marks judged against a pre-set target) and indirect attainment (course-exit, student, graduate and employer surveys). CO attainment is propagated through the CO–PO matrix to yield PO and PSO attainment, and shortfalls feed a documented continuous-improvement loop. It is in the rigour and honesty of this cycle, rather than the mere existence of POs and COs on paper, that the reality of OBE is ultimately tested, equally in botany and zoology.

Cognitive and psychomotor outcomes dominate assessment practice in both disciplines, but the life sciences also declare affective outcomes, conservation ethics, animal-welfare awareness, biodiversity values, and a disposition toward evidence-based environmental responsibility, and these are at present the least systematically assessed component of the outcome architecture. Affective outcomes cannot be assessed by the instruments used for knowledge and technique, but neither are they unassessable: Krathwohl's affective taxonomy supplies a graded structure from receiving and responding through valuing and organisation to characterisation by a value complex, and each level admits observable indicators (Krathwohl, Bloom & Masia, 1964). Three approaches are practicable within existing FYUGP assessment structures. Analytic rubrics can be applied to the field notebook, herbarium and museum record, and internship log book, scoring not only technical accuracy but adherence to ethical collection protocols, restraint in specimen removal, proper attribution of local and traditional knowledge, and evidence of humane handling, criteria that make valuing visible in behaviour rather than in assertion (Brown, Bull & Pendlebury, 1997; Andrade, 2000). Reflective writing, in the form of a short structured reflection appended to each field study, dissection-alternative exercise or internship report, asks students to articulate the ethical reasoning behind a decision they actually took, and can be scored against a rubric distinguishing rote recitation of guidelines from reasoned engagement with a conflict between scientific and welfare interests. Finally, the viva voce components already mandated in practical and project assessment can carry an explicit ethics element, in which a student defends a methodological choice on welfare or conservation grounds. Assessed this way, affective outcomes become part of the attainment record rather than a preamble to it; left unassessed, they remain declarations in the syllabus that no evidence is ever gathered against.

11. An Integrated Life-Sciences Outcome-Based Education (ILS-OBE) Framework

The comparative analysis and synthesis point to a clear conclusion: excellence is distributed, not concentrated, and no single university yet integrates every element well across both botany and zoology. The framework proposed here, the Integrated Life-Sciences Outcome-Based Education (ILS-OBE) Framework, is an attempt to specify that integration. It organises outcome-driven life-sciences education as seven interconnected pillars turning on a central axis of regional biodiversity context (the Himalayan, temperate and arid-zone flora and fauna that give these universities their distinctive material), and it is closed by a continuous-quality-improvement loop so that the whole system learns from its own attainment data. The framework treats botany and zoology as complementary components of organismal biology, sharing an outcome architecture and pedagogy while retaining discipline-specific craft, herbaria and plant field-work on one side, humane, model- and field-based animal study on the other, an integrative stance consistent with wider calls to organise undergraduate biology around unifying concepts rather than around historically separate sub-disciplines (Labov, Reid & Yamamoto, 2010; AAAS, 2011).

The seven pillars are: (1) Graduate-attribute and outcome design, in which POs, PSOs and COs are reverse-engineered from a clear graduate profile using Bloom-aligned verbs, for plant and animal sciences alike (Spady, 1994; Anderson & Krathwohl, 2001); (2) a constructively aligned curriculum, integrating Major, Minor, Multidisciplinary, SEC, VAC and research tracks so that every credit serves a declared outcome (Biggs, 1996); (3) active and experiential pedagogy, matching inquiry, laboratory, field, virtual and blended methods to outcome levels (Freeman et al., 2014; Kolb, 1984); (4) authentic assessment and attainment analytics, with rubric-based practical and project assessment, including observation-, museum- and virtual-dissection-based assessment in zoology, feeding direct/indirect attainment computation (NBA, 2013; Boud & Falchikov, 2006); (5) practical, field and digital infrastructure, from herbaria, greenhouses, museums and aquaria to virtual laboratories, virtual dissection and digital flora and fauna (de Jong et al., 2013); (6) industry, community and research linkage, making employability outcomes real through internships, botanical gardens, agricultural and fisheries stations, sericulture and apiculture units, zoos, sanctuaries and NGOs (Jackson, 2015); and (7) continuous quality improvement, closing the loop by feeding attainment and stakeholder feedback back into outcome and curriculum revision. The framework is depicted schematically in Figure 1 and specified pillar by pillar in Table 6.

Three features distinguish this framework from the generic OBE models on which it builds. First, regional biodiversity is not an application of the framework but its central axis: outcome statements, practical exercises, field work and project topics are anchored to the Himalayan, temperate, sub-tropical and arid-zone systems in which the focal institutions actually sit, so that the same pillar structure produces materially different curricula in Srinagar, Chandigarh and Jodhpur. Generic OBE frameworks are deliberately context-neutral and therefore silent on this. Second, the framework is built around the two discipline-specific practical transitions that define contemporary life-sciences teaching in India, countering plant blindness in botany, and reconstituting zoology practicals after the restriction of dissection, treating them as design requirements of the outcome architecture rather than as incidental constraints; no existing OBE framework addresses either. Third, it closes the loop between attainment measurement and curricular revision as a standing institutional cycle rather than an accreditation event, and it specifies the infrastructural preconditions, herbaria, museums, field-station access, digital resources and technical staffing, without which the cycle cannot function. Existing frameworks generally assume the enabling conditions they require; this one names them, which is what makes it usable as a diagnostic instrument by a department that does not yet meet them.

Table 6. The Integrated Life-Sciences Outcome-Based Education (ILS-OBE) framework: seven pillars, their mechanisms and attainment indicators, turning on regional biodiversity context and closed by a continuous-improvement loop.

Pillar	Purpose	Key mechanisms	Attainment indicators
1. Outcome design	Reverse-design GA→PO→PSO→CO from a graduate profile (botany & zoology)	Bloom-verb CO writing; CO–PO matrix	% COs measurable & mapped; PO coverage
2. Aligned curriculum	Every credit serves a declared outcome	Major/Minor/MDC/SEC/VAC/research aligned	Alignment audit; credit-to-PO coverage
3. Active pedagogy	Match method to outcome level	Inquiry, lab, field, PBL, flipped/blended, virtual dissection	Active-learning share; engagement data

4. Authentic assessment	Judge and improve attainment	Rubrics; project/viva; CIA–SEE; museum/observation & analytics	Direct & indirect CO/PO attainment
5. Infrastructure	Enable practical & digital outcomes	Herbaria, greenhouses, museums, aquaria, virtual labs, e-flora/e-fauna	Facility & virtual-lab utilisation
6. Industry & community	Make employability real	Internships, gardens, fisheries/husbandry stations, zoos, sanctuaries, NGOs, research	Placement/higher-study & internship rates
7. Continuous improvement	Close the loop	Attainment review; stakeholder feedback	Year-on-year attainment gain; actions closed

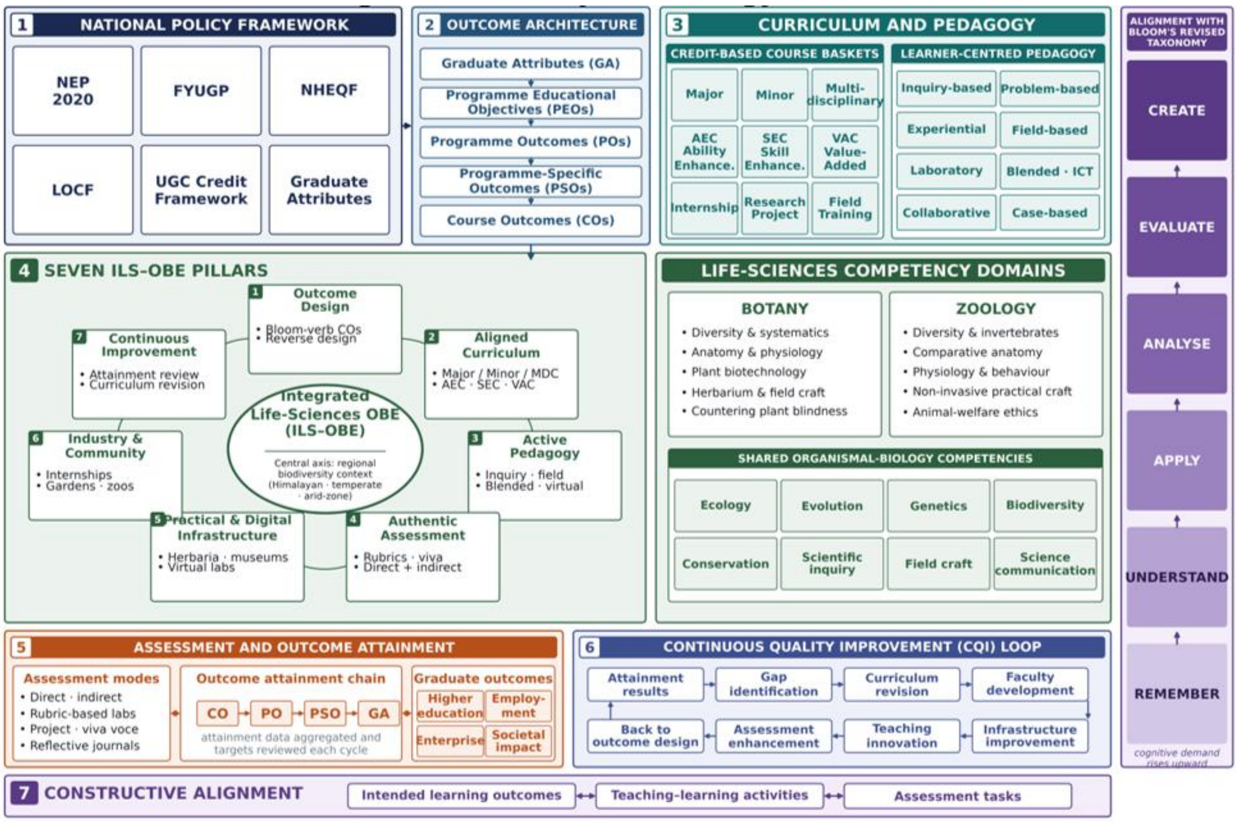

Figure 1. Integrated Life-Sciences Outcome-Based Education (ILS–OBE) framework for undergraduate Botany and Zoology under NEP 2020, illustrating the policy foundation, outcome hierarchy, curriculum and pedagogy, seven OBE pillars, assessment and attainment, continuous quality improvement (CQI), constructive alignment, and alignment with Bloom's revised taxonomy.

The framework's value is diagnostic and generative: a department, of botany, of zoology, or a combined life-sciences unit, can locate itself pillar by pillar against the five comparative dimensions used in Section 6, outcome articulation, practical and field training, assessment maturity, CO–PO mapping discipline and NEP alignment (Table 4), identify its weakest link (most commonly pillars 4, 5 and 7), and target improvement where it matters, rather than treating OBE as a documentation exercise. Crucially, the central axis insists that biological distinctiveness, regional flora and fauna, herbaria and museums, field craft, humane practice and conservation values, be treated not as decoration but as the substantive core around which outcomes, pedagogy and assessment are built, directly countering both plant blindness and the neglect of the invertebrate and non-charismatic animal majority (Wandersee & Schussler, 2001; Sanders, 2019).

12. Challenges in Implementation

Despite structural convergence, several challenges impede substantive OBE in the life sciences, many sharpened by the affiliating-university model that dominates most of these states.

- Faculty capacity and orientation. Writing measurable outcomes, building meaningful CO–PO matrices and computing attainment require training many teachers in both botany and zoology have not received; large guest/contractual cohorts and high student-teacher ratios strain outcome-driven teaching (Rao, 2020).
- Laboratory and field infrastructure. The practical outcomes of botany and zoology presuppose functioning laboratories, microscopes, reagents, greenhouses, herbaria, museums, aquaria and field-tour funding,

unevenly available across hill, rural and remote colleges (Hofstein & Lunetta, 2004).

- Dissection reform without adequate replacement. In zoology, the restriction of animal dissection (UGC, 2014; Akbarsha, 2007) is ethically and ecologically sound, but its educational promise depends on adequate substitutes, models, museum specimens, permanent slides, virtual-dissection software and structured field protocols, that resource-constrained colleges have not always been able to provide, risking a net loss of structural-anatomy and psychomotor learning where replacements are missing.
- The digital divide. The ICT-enabled provision on which much of the NEP-era curriculum depends presupposes an infrastructure that is unevenly distributed, and the dependency is strongest precisely where the infrastructure is weakest. Virtual dissection software, physiology simulations, digital herbaria and museum databases, online floras and keys, SWAYAM and MOOC integration, and attainment-management software all require reliable electricity, adequate bandwidth, sufficient client hardware and institutional licences. Hill, remote and rural colleges in Himachal Pradesh, Uttarakhand and Jammu & Kashmir, and in the arid districts of Rajasthan, contend with intermittent connectivity, seasonal disruption, small and ageing computer laboratories shared across departments, and licence costs that fall outside recurring budgets; students in these institutions are also less likely to hold a personal device or an adequate home data connection, so provision that assumes out-of-class digital access silently excludes them. The consequence is a compounding inequity rather than a simple shortfall: the colleges least able to maintain herbaria, museums, aquaria and field budgets are the ones for which virtual resources were supposed to compensate, so where the digital substitute also fails, the practical curriculum contracts twice over. Addressing this requires provision that does not assume continuous connectivity, offline-capable and low-bandwidth software, institutionally hosted mirrors of digital herbaria and museum collections, consortium licensing negotiated at state or regional level rather than by individual colleges, and shared regional digital facilities on the model of the shared practical facilities recommended in Section 13, together with the recognition that digital access is now itself a component of practical infrastructure and should be audited as such in the attainment cycle rather than assumed.
- Assessment authenticity and standardisation. Continuous internal assessment can inflate marks and vary between colleges under a common affiliating examination; ensuring CIA measures outcomes rather than compliance is difficult at scale (Black & Wiliam, 1998).
- Absent rather than tokenistic mapping and attainment. The accreditation literature warns that CO–PO matrices are often filled for audit and that indirect-attainment surveys are perfunctory, hollowing out the improvement loop (NBA, 2013). For undergraduate botany and zoology the prior problem is that the apparatus is not published at all: no curriculum examined for this review carries a mapping matrix, a stated attainment target or a rubric, so there is no documentary basis on which either a diagnostic or a ritual use of it could be assessed.
- Curricular overload and flexibility management. The multiplicity of baskets, exit points and internship logistics burdens departments still migrating from annual to semester systems.
- Erosion of disciplinary depth. Multidisciplinary breadth, if poorly advised, can thin the core systematics, physiology, comparative anatomy and laboratory/field craft that professional and research destinations in both botany and zoology require (BIO2010; NRC, 2003).

13. Recommendations and the Way Forward

The gap between the promise of NEP-aligned OBE and its classroom reality can be narrowed through targeted, achievable measures, organised by the ILS-OBE pillars.

1. Sustained faculty development on outcome writing, Bloom-aligned assessment, rubric construction and attainment computation for both botany and zoology, treated as core professional development rather than one-off workshops (pillars 1 & 4).
2. Strengthened practical and field infrastructure through shared regional facilities, mobile laboratories, virtual-lab and virtual-dissection supplementation, digital herbaria and museums, and dedicated field-study funding, with explicit provision for credible dissection alternatives in zoology (pillar 5).
3. Genuinely diagnostic attainment analysis, honest target-setting, triangulated direct/indirect evidence, and visible action on shortfalls, closing rather than documenting the loop (pillars 4 & 7).
4. Deeper industry, research and community linkage for internships and projects, nurseries, botanical gardens, agricultural, fisheries and forest stations, sericulture and apiculture units, zoos, sanctuaries, biotechnology firms and NGOs, and measurement of graduate destinations (pillar 6).
5. Protection of core disciplinary depth by advising coherent pathways and safeguarding essential systematics, physiology, comparative anatomy and laboratory/field craft within a flexible structure (pillar 2).
6. Equitable digital access as a component of practical infrastructure, through consortium licensing of virtual-dissection, simulation and database resources negotiated at state or regional rather than college level, institutionally hosted mirrors of digital herbaria and museum collections, offline-capable and low-bandwidth provision for hill, remote and rural colleges, and explicit auditing of digital access in the infrastructure review rather than its assumption (pillars 5 & 7).
7. Leveraging regional biodiversity, Himalayan flora and fauna in HP, Uttarakhand and J&K; arid-zone flora and fauna in Rajasthan, as signature, employable competence and authentic experiential learning, and

embedding conservation and animal-welfare ethics as graduate attributes (central axis).

8. Digitised OBE records through attainment software integrated with examination data, reducing the administrative burden that pushes departments toward tokenism (pillar 7).

These eight recommendations are not equivalent in cost, in the time they take to yield results, or in how far they lie within a single department's control, and treating them as an undifferentiated list invites the familiar outcome in which the cheapest are adopted and the consequential ones deferred. Two are foundational and resource-intensive: sustained faculty development (recommendation 1) and strengthened practical and field infrastructure (recommendation 2). Both require recurring budget, institutional or state-level commitment and a multi-year horizon, and neither can be accomplished by a department acting alone, but nothing else on the list substitutes for them, because outcome statements are only as good as the teachers who write and assess against them, and practical outcomes are only attainable where the facilities to attain them exist. These should therefore be treated as the primary claims on resources even though they yield the slowest visible returns. Two others are immediately actionable at departmental level and at near-zero marginal cost: genuinely diagnostic attainment analysis (recommendation 3) and digitised OBE record-keeping (recommendation 8). The first requires a change of practice rather than of provision, honest target-setting, triangulation of direct and indirect evidence, and minuted action on shortfalls, while the second reduces the administrative burden that drives departments toward tokenism in the first place and creates the data infrastructure on which graduate-destination measurement depends. These two should be undertaken first, both because they are achievable within a single academic cycle and because the attainment evidence they generate is what identifies where faculty development and infrastructure investment are most needed, making them a precondition for spending recommendations 1 and 2 well. Of the remainder, equitable digital access (recommendation 6) is intermediate in cost but disproportionately consequential for the institutions furthest from the regional mean, and is most efficiently pursued collectively rather than college by college; the final three, industry, research and community linkage (4), protection of core disciplinary depth (5), and leveraging regional biodiversity as signature competence while embedding conservation and welfare ethics as graduate attributes (7), depend substantially on local context and existing partnerships and are best pursued incrementally alongside the others rather than sequenced strictly after them.

14. Conclusion

The principal finding is that structural convergence is substantial but attainment is not. A common outcome architecture, credit structure, skill menu, practical-and-field regime and two-part assessment system are now in place across the region for both disciplines. Excellence within that structure, however, is distributed rather than concentrated: no single institution integrates every element well across both botany and zoology.

The strengths and weaknesses identified are correspondingly uneven. Outcome articulation and credit flexibility are widely established; the formal machinery of mapping and attainment is not, being absent from every undergraduate botany and zoology curriculum examined here including those of the most-cited exemplars; faculty capacity to write, teach and assess against outcomes is not, practical and digital infrastructure is unevenly distributed and sharply so between well-resourced and remote institutions, attainment cycles too often document rather than diagnose, and in zoology the ethically sound restriction of dissection has not always been matched by adequate replacement.

The remedies follow from this diagnosis and are not equally urgent. Diagnostic attainment analysis and digitised outcome records are achievable within one academic cycle and generate the evidence that should direct everything else; faculty development and practical, field and digital infrastructure are the slower, costlier investments that no procedural improvement can substitute for.

Whether OBE fulfils its promise in the life sciences will therefore depend less on the elegance of any syllabus than on sustained investment in faculty capacity and infrastructure, and on the integrity of the attainment cycle, the conditions under which declared outcomes become demonstrated competence.

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