Benchmarking for Quality and Standards in Higher Education:

Pilot : A Template for Developing a Matrix for Benchmarking

Importance of Benchmarking

The role of Benchmarking for quality and standards in higher education is increasingly being realized the world over. Benchmarking facilitates mobility, employability and promotes access to quality higher education **for all.** It is in this context that the importance of National Qualifications Frameworks (NQF) is also becoming centre stage in education and subject-specific benchmarks set out expectations about standards of degrees in a range of subject areas. These subject-specific quality standards provide a key means to build an outcomes-based approach to curriculum development and the modality of its transaction for ensuring qualitative teaching and learning standards. This Concept Note outlines contours of such an exercise in one of the foundational areas relevant to introductory Collegiate / University level Chemistry course.

Underlying Assumptions

The underlying assumptions for this approach to quality and standards are that students must understand: what Chemists do; what they think is important; what points of view they tend to emphasize; what they feel the limitations and future of Chemistry are. The system with which chemists work are generally more complicated than those of major interest to the physicist just as those of the physicist are generally more complicated than those of the mathematicians. The trend continues as the student goes to Engineering, the life sciences and the humanities. This note restricts the discussion to the subject of Chemistry and has attempted a template for developing a matrix for benchmarking which can lead to a better defined focus on learning outcomes.

The Scope of Chemistry

The canvas of Chemistry is broadly covered in seeking answers to the following questions. Each question includes several topics that when covered will provide a complete answer to the main/broad question. The questions define the scope of Chemistry in terms of Energetics, Dynamics, Structure.

- What models are useful in describing molecular behaviour ?
- What holds molecules together ?
- To what extent do reactions occur ?
- How do reactions occur ?
- How does structure affect properties ?
- How are chemical reactions used ?

Chemists' Skills

It is important to realise that the students of chemistry must be capable of both rigorous and intuitive decision making and **for this reason** they must seek to develop not only the skills of more rigorous Physicists but also those of more intuitive Life Scientists. The underlined thread in the development of concepts in Chemistry must be realised through the following steps :-

- making and recording observations of a phenomenon
- search for regularities in the recorded observations;
- confirming that observations exist under identical conditions of experiment;
- finding why the regularities exist; and
- constructing hypothesis, theory, law to fit the observations.

These aspects are sought to be developed through understanding the developments in our knowledge of the Structure of Atom. Incidentally, this should provide a solid foundation for discrete nature of matter, electric charge and energy that is, the concept of Quantization.

Quantization of Matter

The learning outcomes which define the benchmarks in this area include :-

- The learner is able to discern the difference between evidence and proof in Science.
- cite **Physical evidences** for the quantized (that is, discontinuous, discrete, particulate) nature of matter.
- explain how phenomena like filtration, evaporation, distillation, sublimation, crystallization, diffusion provide evidence for the discrete nature of matter'.
- infer certain attributes of particles – motion, space, mass
- cite **Chemical Evidences** for the atomic nature of matter elaborating them through the Laws of Chemical Combination :-
  - Law of Conservation of Mass
  - Law of Definite Composition
  - Law of Multiple Proportions
  - Law of Equivalent Weights (Reciprocal Proportions)
  - Law of Gaseous Volumes
- Deduce how the Law of Multiple Proportions provide real evidence for the discrete nature of atoms.

Quantization of Electric Charge

- Explain how electrical nature of matter (also implying atoms) is exemplified by phenomenon of Electrostatics, Faraday's Laws of Electrolysis.
- Explain how the discrete nature of electric charge can be inferred from the experimental data on Faraday's Second Law of Electrolysis.

- Explain how the Quantification of electric charge by Millikan's Oil Drop experiment gave a proof for the quantized nature of electric charge.

Quantization of Energy

- Explaining how energy is stored in atoms; an analysis of potential and kinetic energy components; importance of Virial Theorem
- Scanning the phenomenon of Black Body Radiation to explain Planck's energy equation; $E=h\nu$
- Implications of the phenomenon of ultraviolet catastrophe
- How the photoelectric effect supported quantization of energy – package of Photons.

Sub Atomic Particles

- Understanding how the discovery of sub-atomic particles exemplify implications and growth of Models in Science.
- Explanation of the phenomenon observed in the gas discharge tube ultimately establishing discrete sub-atomic particles with electric charge with e/m ratio for electron (constant) and e/m ratio for proton (variable) why ?
- Arrangement of electrons and protons in the atom and the outcome of alpha particle scattering; and the questions that remain unanswered
- Understanding the discrepancy in atomic number-atomic mass of elements and the discovery of a neutral particles with mass equivalent to that of protons.
- Emergence of the Planetary model of the atom with nucleus at the centre and electrons in orbits outside.

Era of Newtonian Mechanics ends with Bohr Atom

- Understanding how the experimental fact that a charge in motion should radiate energy (Faraday's laws of electromagnetic induction) was answered by Niels Bohr through the Stationary energy states of the Bohr model.
- Mathematical model of the Bohr atom and Hydrogen atom spectra and an excellent match of the two.
- Implications of Quantization of angular momentum

  $mvr = nh / 2\pi$ $(n = 1,2,3.....)$
- Mismatch of the phenomenon of K-Capture with Bohr atom.

The Advent of Quantum Mechanics	- Establishing wave particle duality (de-Broglie) - Implications of The Uncertainty Principle (Heisenberg) - Wave equation. - The probability picture of the atom_ Radial Probability, Angular Probability. - Implications of Quantization – Principal, Azirmuthal, Magnetic and Spin Quantum Numbers. - How Quantum mechanics helps deeper understanding of Energetics, Dynamics and Structure.
Pedagogical Supports	- Class room experiments, demonstrations. - Audio – Video Support to concept understanding. - Experimental data to support theoretical models. - Theoretical models to support experimental data.
What Next ?	- Crosscutting many areas, particularly in Chemistry and Physics, the total spectrum of details in the area of Atomic Structure will be covered in this Benchmarking exercise. - Development of Assessment Formats for all levels of hierarchy concepts.
Time Frame	1. This will be a Pilot to detail Benchmark (overarching areas have been given) for each of the parameters outlined. 2. The Module of Benchmarking will be comprehensive when fully developed in terms of learning outcomes. 3. Experiment, Demonstration, Audio-Video clips will have to be incorporated in development and understanding of concepts. 4. **The task will be accomplished by two academics, one in the field of Chemistry and the other in the field of pedagogy and assessment and will require three to four months of time as a whole time responsibility.** 5. Once the Benchmark matrix is finalised, it can be fine tuned and used as a template for similar exercises in other topics of Chemistry and other subjects.
Extension of Task	- Once the Pilot is developed, teams of experts will have to be identified in different subjects and a mechanism of coordination of this task will be required for a comprehensive Benchmarking exercise.
Financial Implications for the Pilot	- An appropriate honorarium may have to be decided for the two academics for developing the Pilot Benchmarking matrix.

References

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