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Designing undergraduate experimental module for analysis of metal ion content present in hard water

Indrani Das Sen, Chemistry Group, HBCSE (TIFR), Mumbai

Background- What is the need to redesign experimental modules ?

Typical laboratory manual at undergraduate (UG) level in chemistry -

- Experimental write-ups give aims of the experiment, small introduction, well-defined procedure, data to be collected followed by inferences to be drawn
- Write-ups are more recipe-like and verification type
- Very little connections between theory and experiments
- Constraint students' actions and decision making ability
- Typical experiments are synthesis and titration based with few instrumental based experiments
- Informal discussions with students reveal that outcomes are already known, often struggle with language, representations, no new learning happen in the lab setting, etc.

Chemistry Education Research (CER) literature informs that chemistry laboratory work at UG level should have the following elements-

1. Practical skills- safety, hazards, procedures, handling instruments, observation and measurement, evaluation and interpretation of results, planning and selection of methods, etc.
2. Transferable skills- team working, time management, communication, presentation, data processing, designing strategies, problem solving, etc.
3. Intellectual stimulation- connections with 'real world' and developing interest in chemistry

Can opportunities be generated in conventional chemistry lab set-up to help students to learn/correlate concepts with experimental domain?

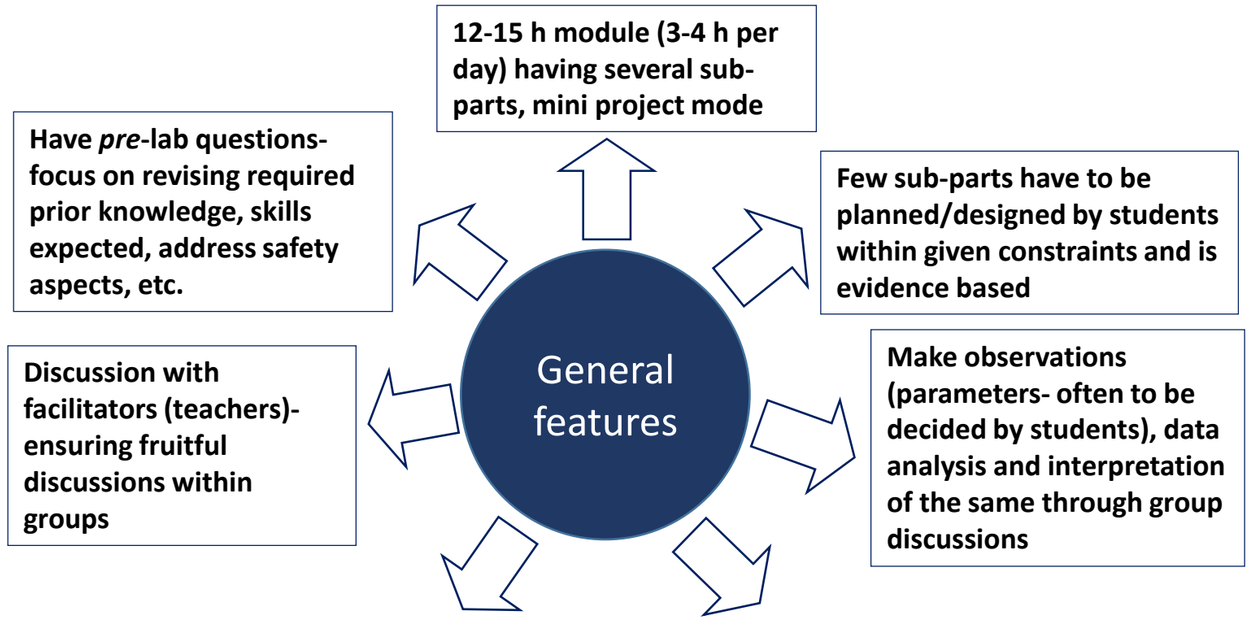
Ref: Carnduff, J., & Reid, N. (2003). *Enhancing Undergraduate Chemistry Laboratories*, Royal Society of Chemistry, London

Talanquer, V. (2012). Chemistry Education: Ten Dichotomies We Live By. *Journal of Chemical Education*, 89, 1340-1344

Development of exploratory/inquiry based experimental modules (Activity under NIUS Chemistry Programme)

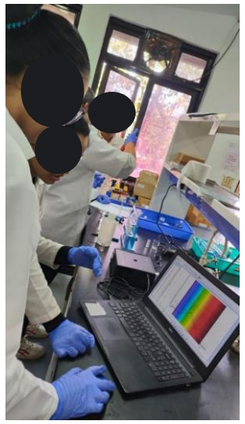
Ongoing work (with chemistry teachers from state colleges of Mumbai and Pune)
Experiments adapted from Mumbai/Pune University chemistry laboratory syllabus

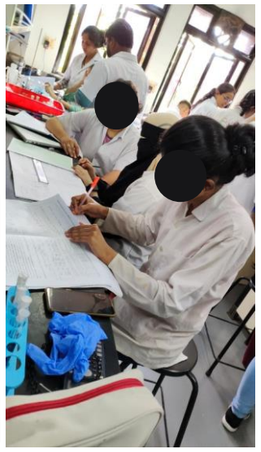
Level- Chemistry lab courses at UG level, Approach- Partial *pre*-lab-lab- *post*-lab
Field testing- students in NIUS chemistry camps (Dec 2022 and June 2023)



Snapshots





Exploring estimation of Ca(II) in presence of Mg(II) using disodium salt of ethylene-diammine acetic acid (Na_2EDTA) spectrophotometrically

Context- Water contain varying amounts of metal ions, of which both Ca(II) and Mg(II) can form insoluble salts with carbonates or sulphates and cause economic and often health problems. Thus, amount of these ions need to be estimated before its use as potable water or in industry.

Pre-requisites of the module - complexometric titrations (introductory concepts) color and wavelength correlation, absorbance and Beer-Lambert's Law (covered as part of *pre-lab* discussions)

Technical Skills required- Solution preparation and making dilutions, handling spectrophotometer/colorimeter, observations w.r.t. color/solubility changes, plotting of graphs and mathematical manipulations, etc.

Different Sub-parts of the module –

1. **Exploring suitability of calmagite as a possible indicator at different pH (buffered) and over time-** (evidence based investigation and decision about choice of pH based on inferences from observations, notion of independent/dependent variable, experimental conditions)
2. **Determining working concentration range of calmagite (check for validity of Beer- Lambert's law at fixed pH value)-** (decision about choice of λ (wavelength) of indicator solution for calibration plot, max/min concentration of indicator to be prepared for further analysis, what to plot for validating Beer-Lambert's law (x-axis/y-axis, linear/curved plot, etc.)
3. **Stability of colour of Indicator + Ca(II)/Mg(II) solutions (buffered) at different pH and over time-** (gathering visual and instrumental evidences of color change of indicator in absence/presence of metal ions and at appropriate pH to be used for further analysis)
4. **Investigating intervention of Mg(II) - does it interfere with estimation of Ca(II) using Na_2EDTA ?-** (decision about color change of indicator; interpretation and correlation with different species of indicator/Na_2EDTA present in solution, quantitative analysis of data)

Implementation Challenges

- Requires 3-4 half-day working lab.
- Being exploratory in nature, require teachers to monitor student progress (decision making and trouble shooting)
- Teachers needs to understand the objectives of the sub-parts of the module for meaningful discussion with students
- Expected technical skills need to be demonstrated and practiced with students
- Prior trials have to be conducted by teacher for anticipating challenges in the sub-parts

Learnings from the module and the lab

1. **Helps in Understanding-**
   - Steps of the procedure and their importance
   - Variables involved (independent/dependent)
   - Conditions/Constraints of the given experiment
   - Factors to be considered for planning
2. **Planning activity-** presents opportunities for discussing and making informed choices, taking decisions, gives an idea about what is meaning of designing an experiment
3. **Group work-** enhances soft/transferable skills - communication, time management, confidence and team building, presentation, drawing inferences, etc. of students
4. ***Pre*-lab activity-** recollection of theoretical concepts, safety, technical skills associated with the experiment and mentally prepare for the experiment
5. **Decision making ability-** decide what/when to observe and record, correlate different sub-parts of the module (e.g., structure of indicator with color changes) to make proper inferences
6. **Post lab - Reflective thinking-** realizing constraints of the system under study, modelling, limitations, interpretation, correlation of various sub-parts, drawing inferences

Feedback from students-

"A clear cut procedure was not given which helped us to explore the experiment in our own way"
"I now know how the values of concentration, time, pH (*in an experiment*) are decided, why certain range of values yield results, how errors can be minimized, how to interpret data, not to disregard anamoly results"
"The goal of the experiment was to explore estimation of Ca(II) using Na_2EDTA spectrophotometrically in presence of Mg(II)"

(NIUS Chemistry Camp- December 2022, June 2023)

Acknowledgements

NIUS chemistry programme, HBCSE-TIFR
Anupa Kumbhar, Savitri Bai Phule Pune University
Members of Chemistry Group , HBCSE-TIFR