Micro-Macro Thinking Skill

1. What is Micro-Macro Thinking?
We define ‘micro-macro thinking’ as the ability to establish a link between theoretical variables in a microworld and its corresponding manipulable variables in a macroworld in order to predict the functionality for any given system. In any given situation, in order to establish this micro to macro link, sub skills of making Observations in the micro world-Predicting macroscopic outcomes-Testing these outcomes against experimental evidence-Revising prediction if necessary (O-P-T-R) need to be developed.
Other thinking skill which is similar to this skill is Hypothetico-deductive reasoning (HDR) (Lawson 2000)

2. Why to teach Micro-Macro Thinking Skill?
• Learning how to relate macroscopic phenomena to microscopic models, here referred to as micro-macro thinking, is found to be problematic for students as they have difficulty in bridging the huge mental gap between macro and micro worlds (Eilam, 2004; Harrison & Treagust, 2003; De Vos & Verdonk, 1996; Gilbert & Treagust, 2009; Wiser & Smith, 2008).
• In the process of sense making, students try to deal with an invisible world (of molecules and atoms) which they have to accept on the basis of ‘authority’, not on the basis of evidence and argument as would be the case in an effective curriculum aimed at meaningful understanding (van Berkel et.al., 2009). Hence, designing explicit instruction for it is necessary.
• During their learning process, students do the exercises and experiments, and view demonstrations do not necessarily recognize that these portions of the curriculum are interrelated and are based upon a common conceptual underpinning (Hinton & Nakhleh, 1999).
• Research shows that students have difficulty transferring from a macroscopic level of representation to the microscopic level (Gabel, 1998). To avoid mixed messages, it is important to have in-depth knowledge of the problematic features of micro–macro thinking and to understand what it is that is to be communicated to students and how this is best communicated to them (van Berkel, Pilot & Bulte, 2009).
• A key aspect of systems thinking is the need to be able to think backward and forward between general systems models and concrete objects and processes (Wilensky & Resnick, 1999). This is addressed when students develop the skill of micro-macro thinking.
• An important aspect of scientific modeling is to explain the macroscopic outcome or observed physical phenomena by applying a model at a microscopic level (Etkina, Warren & Gentile, 2006). The macroscopic level comprises the tangible
and visible and the microscopic level often comprises an invisible particulate level, such as the electrons, molecules, or atoms (Johnstone, 1982).

3. **Sub-skills of Micro-Macro Thinking Skills**

We define 'Micro-Macro Thinking Ability' as a measurable set of abilities in which students learn to make predictions, test predictions with respect to experimental results, and revise predictions if necessary. These abilities and constituent sub-abilities are:

- In the prediction phase, students should be able to state what might happen to the state of a system if a certain parameter was varied on the basis of an appropriate principles/theory. Sub abilities include:
  - Students should be able to first accurately describe what is observed at a microscopic level.
  - Students should be able to devise an explanation for an observed pattern, make a reasonable prediction based on explanation.
  - Students should be able to make a reasonable prediction based on explanation.

- In the testing phase, students should be able to analyze if the predicted answer tallies with the experimental outcome post performing the experiment. Sub ability includes:
  - Students should be able to decide whether the prediction and the outcome agree/disagree.

- In the revision phase, students should be able to alter the explanation based on which the prediction was made and justify the changes being made. Sub ability includes:
  - Students should be able to revise the explanation when necessary.

3. **How to choose topic to teach Micro-Macro thinking skill?**

A topic suitable for Micro-Macro thinking skill is one which should have

1. Two levels.
2. The two levels should interact with each other.
3. Explanation of the topic should be dependent on both levels.
4. Explanation in one level affects measurement in another level.
5. Interlinked variables at both microscopic and macroscopic levels.

4. **Learning objectives for Micro-Macro thinking skill**

Learners should be able to:

- Students should be able to first accurately describe what is observed at a microscopic level.
- Students should be able to devise an explanation for an observed pattern, make a reasonable prediction based on explanation.
- Students should be able to make a reasonable prediction based on explanation.
- Students should be able to decide whether the prediction and the outcome agree/disagree.
- Students should be able to revise the explanation when necessary.

5. **Learning objectives for Micro-Macro thinking skill in a domain**
Application in domain 1 (Diode Theory):
• Describe the microscopic model of a PN junction in terms of electron motion and size of depletion layer as the external voltage is varied.
• Predict the macroscopic current versus voltage characteristics of a diode based on the microscopic model of a PN junction.
• Test your prediction of the current versus voltage characteristic curve by comparing it with a real world experimental outcome.
• Revise your prediction of the current versus voltage characteristics based on the microscopic model of the PN junction.

Application in domain 2 (Mendelian Genetics):
Suppose learners are given a problem on variation in inheritance patterns. Eg. “Suppose you are interested in breeding varieties of flowers for gardeners. You have pure-breeding plants of a particular kind which produce red flowers and small leaves. You also have pure-breeding plants of the same species which have blue flowers and large leaves. The F1 plants which look all same underwent self-breeding and there were 1000 plants in total in the F2 generation and the results were: (red flowers, large leaves - 62) (red flowers, small leaves - 188) (blue flowers, large leaves - 63) (blue flowers, small leaves - 187) (purple flowers, large leaves - 124) (purple flowers, small leaves - 376). Why did variations in offspring appear in F2 generation?”

In order to reason about particular patterns of inheritance seen in offspring, learners should be able to:
• Form explanation (hypothesize) focussing on Mendelian and Non-Mendelian inheritance along with reasoning.
• Design experiment to determine ratio of genotypes of offspring specifying variables like no. of plants, no. of generations, type of cross etc.
• Predict result about ratio of genotypes in offspring based on values of variables chosen.
• Observe experimental outcome based on breeding output.
• Compare result (decision making) based on predicted and observed results about ratio of offsprings.
• Revise design of experiment or hypothesis.

References:


