From Wonder to Mastery
by John Mays

In the coming chapters, as we work our way toward a pedagogy in which students are actually learning science, we must bear in mind that the content of our courses must address the tools as well as the facts. The basic tools of science are listed below. I am listing them here because we address many of these in more detail in later chapters.

1. Facility at deep observation, focusing on the characteristics of an object or organism, and describing these characteristics with accurate sketches or written descriptions.
2. The ability to think of matter in scientific terms, observing, classifying, and questioning such things as the chemical and physical properties of a substance, and the physical laws which govern physical and chemical processes.
3. Knowledge of different units of measurement, the USCS, SI, and MKS systems of units, and proficiency at performing unit conversions (dimensional analysis).
4. The ability to describe physical laws in terms of the mathematical relationships embedded in equations, such as direct and inverse proportion, independent and dependent variables, the behavior of different variables under different conditions, and linear and nonlinear functional relationships.
5. The ability to describe the steps in the Scientific Method, why they are necessary for a valid controlled experiment, and why this method has enabled science to be so successful over the past few hundred years.
6. Knowledge of the difference between accuracy and precision and how each relates to taking measurements.
7. The ability to formulate a quantitative hypothesis.
8. Competence at effectively documenting an experiment in a lab journal.
9. The ability to write an effective lab report from scratch, including clear descriptions of background and procedure, and analysis of results.

10. The ability to use computer tools in the design of tables and graphs and the creation of lab reports.
11. The ability to manipulate data, represent data in tables and graphs, and compute the percent difference between a prediction and an experimentally determined value (i.e., "experimental error").
12. The ability to identify reasonable and significant factors contributing to percent difference.
13. The ability to estimate the uncertainty in a measurement.
14. Proficiency at measurement techniques and standard laboratory practices, and skill at using proper care with laboratory equipment.
15. The skill of exploring the uses and limitations of unfamiliar scientific equipment.
16. The ability to set up a scientific graph with appropriate labels and scales, and use it to compare theoretical and experimental values and trends.
17. The ability to identify outlying data and suggest alternatives for dealing with outlying data.
18. The ability to identify reasonable solution strategies for problems when a method is not readily apparent.
19. Proficiency in the application of mathematics to the solution of scientific problems.
20. The ability to use mental math to get quick, approximate answers.
21. The ability to recognize when calculated answers or experimental data are unreasonable or erroneous.
22. An appreciation for the level of effort required to achieve mastery in a new area of study.

All these skills should be addressed in an effective secondary science program. The list is long and no single science course can address every one of the skills in depth. Development of some of these skills should begin at the very early grades of elementary school. Most secondary courses should hit hard on many of the items in the list. Some of the skills (such as estimating uncertainty or exploring the limits of unfamiliar equipment) are typically addressed only in upper-level courses.