

PROCESS SKILLS FOR LIFE SCIENCE (04)

Training Guide

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This event is a lab-oriented competition involving the fundamental science processes of a middle school life-science program. The event is not meant to be a comprehensive biology course. If specific content is needed when students are being tested on certain process skills, the supervisor will provide that content.

SCIENCE PROCESS SKILLS

The event consists of a series of biological questions or tasks that involve the use of one or more process skills. Science process skills are classified as basic skills and integrated skills. These skills can be accessed by applying them to a series of lab station activities which are included in the Guide for Supervisors, Coaches and Students. Tips to assist students in their preparations are also included in this guide.

Basic Science Process Skills:

- **Observing** - using your senses to gather information about an object or event. It is a description of what was actually perceived. This information is considered qualitative data.
- **Measuring** - using standard measures or estimations to describe specific dimensions of an object or event. This information is considered quantitative data.
- **Inferring** - formulating assumptions or possible explanations based upon observations.
- **Classifying** - grouping or ordering objects or events into categories based upon characteristics or defined criteria.
- **Predicting** - guessing the most likely outcome of a future event based upon a pattern of evidence.
- **Communicating** - using words, symbols, or graphics to describe an object, action or event.

Integrated Science Process Skills:

- **Formulating Hypotheses** - stating the proposed solutions or expected outcomes for experiments. These proposed solutions to a problem must be testable.
- **Identifying of Variables** - stating the changeable factors that can affect an experiment. It is important to change only the variable being tested and keep the rest constant. The one being manipulated is the independent variable; the one being measured to determine its response is the dependent variable; and all variables that do not change and may be potential independent variables are constants.
- **Defining Variables Operationally** - explaining how to measure a variable in an experiment.
- **Describing Relationships Between Variables** - explain relationships between variables in an experiment such as between the independent and dependant variables plus the standard of comparison.
- **Designing Investigations** - designing an experiment by identifying materials and describing appropriate steps in a procedure to test a hypothesis.
- **Experimenting** - carrying out an experiment by carefully following directions of the procedure so the results can be verified by repeating the procedure several times.
- **Acquiring Data** - collecting qualitative and quantitative data as observations and measurements.
- **Organizing Data in Tables and Graphs** - making data tables and graphs for data collected.
- **Analyzing Investigations and Their Data** - interpreting data statistically, identifying human mistakes and experimental errors, evaluating the hypothesis, formulating conclusions, and recommending further testing where necessary.
- **Understanding Cause and Effect Relationships** - what caused what to happen and why.
- **Formulating Models** - recognizing patterns in data and making comparisons to familiar objects or ideas.

GUIDE FOR SUPERVISORS, COACHES, & STUDENTS

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Lab Stations and Tasks for Assessing Process Skills

Below is a list of lab stations and types of questions or tasks which might be used to assess science process skills. To allow most students to be successful, it may be a good idea for event supervisors to vary the difficulty of questions at each station!

Lab Safety

- Distinguishing "safe" behaviors vs. "unsafe" behaviors, identifying safety symbols, evaluating situations -- what to do "if" or what's wrong.
- Identifying the proper techniques to handle lab emergencies.

Observations

- Using senses to notice specific features.
- Identifying similarities and differences in features.
- Identifying qualitative and quantitative changes in conditions.
- Using observable properties to classify objects, organisms or events.

Inferences

- Formulating assumptions based upon observations.
- Distinguishing between observations and inferences.
- Using observations and inferences to identify testable questions or problems.

Problem

- Using observations to propose a topic for experimentation.
- Narrowing the scope of the topic to specific testable aspects.
- Formulate problems within the specific aspects of the topic which are clearly testable.
- Identify which of the problems can be tested with materials available.
- Generalizing variables to be considered in testing the problem such as "The effect of (the independent variable) upon (the dependent variable.)"

Hypothesis

- Proposing a hypothesis for a given problem.
- Predicting the effect of the change in the independent variable upon the dependent variable.
- Explaining the relationship or trend that is expected to occur.
- Providing rationale for a hypothesis or prediction.
- Determining the testability of a hypothesis based upon materials provided.
- Evaluating statements presented with a set of data as to their appropriate label.: **1.** logical hypothesis, **2.** illogical hypothesis of contrary to data, **3.** not a hypothesis, but a restatement of data, **4.** reasonable hypothesis, but not based on data

Predictions

- Predicting the results for a proposed lab test or setup.
- Selecting predictions based upon previously observed patterns.
- Providing rationale for predictions.

Lab Equipment

- Identifying pieces of lab equipment and their function.
- Identifying appropriate pieces of equipment to perform a specific task.
- Selecting and using the appropriate piece(s) of lab equipment for a task.

Procedures

- Analyzing procedures for flaws in design.
- Identifying the proper set of equipment for carrying out an experimental procedure.
- Arranging steps of procedures in the appropriate order.
- Determining the repeatability of a procedure.
- Identifying an appropriate procedure to test a problem.

Design Analysis

- Analyzing designs for experiments relative to problem,
- Evaluating the basic assumptions used in the design of the experiment.
- Identifying components as the independent variable, dependent variable, constants (controlled variables), standard of comparison (control), and time period for the test.
- Evaluating the procedure for repeatability.
- Evaluating the materials and appropriateness of the steps in the procedure.
- Identifying appropriate types of qualitative and quantitative data to be collected.

Measurement

- Identifying the capacity, range, and increments of measuring devices as a ruler, graduated protractor, caliper, cylinder, pipet, syringe, or thermometer.
- Identifying length, temperature, volume, and mass to the capacity of the instrument.
- Converting units within the metric system.
- Reading the meniscus when measuring liquids in a cylinder.

Balances

- Identifying types of balances as electronic and triple beam.
- Determining the capacity of the balance, its increments, its readability, the types of auxiliary weights, the parts of the balance and their function.
- Determining the mass of an object to the capacity of the instrument.
- Using auxiliary weights to reach the capacity of a triple beam balance.

Microscopy

- Understanding of parts of microscope & their function, magnification, appearance of images, resolution, changes in field with magnification, types of microscopes and their uses.
- Preparing a wet mount.
- Using a light microscope to perform a requested task.
- Using a dissecting microscope to perform a requested task.

Chemical Analysis

- Identifying the appropriate reagents for specific chemical testing.
- Using reagents as pH paper, iodine, glucose test paper, bromthymol blue for chemical analysis.
- Interpreting the results of reagent data.

Dichotomous Key

- Using observations to formulate a dichotomous/taxonomic key.
- Identifying individuals or objects using a dichotomous key.
- Identifying similarities and differences in characteristics from a dichotomous key.

Calculations

- Using measurements to determine area, volume, percentages, probabilities, ratios.
- Determine population density of a sample.
- Performing statistical analysis of raw data as mean, median, mode, and range.

Data Presentation

- Preparing an appropriate data table, chart, diagram, illustration.
- Evaluating the presentation of data.

Graphing

- Selecting the appropriate graph for a set of data as line, bar, and pie graphs.
- Identifying the title, source, independent variable & dependent variables, and the legend.
- Scaling each axis for a graph.
- Preparing a line, bar or pie graph to represent a set of data.
- Predicting data points not included in a given graph and/or making a best line fit.
- Interpreting a graph and making predictions or inferences based upon the data on a graph.

Analysis of Data

- Identifying sources of experimental error or human mistakes in the data.
- Determining the validity of results using qualitative and quantitative data.
- Interpreting graphs as well as charts and diagrams as food webs, pedigrees, Punnett squares, food labels, energy and food pyramids, relationships of organisms.
- Identifying data which supports or rejects a hypothesis.
- Identifying discrepancies between stated hypothesis and actual data.
- Understanding cause and effect relationships.

Errors

- Identifying human mistakes or blunders.
- Identifying experimental errors as systematic errors and random errors.
- Making recommendations for eliminating future mistakes or experimental errors.
- Explaining the effects that human mistakes or experimental errors upon results.

Conclusions

- Selecting the most logical conclusion for given experimental data.
- Accepting or rejecting hypotheses based upon data analysis.
- Proposing a new hypothesis for rejected hypotheses.
- Formulating models
- Proposing a future test for inconclusive results.

Some Helpful Hints for Event Supervisors:

- It may help to have questions laminated or placed in sheet protectors. This procedure eliminates damage or tampering during competition.
- Taping questions to the table helps to keep stations organized and undisturbed.
- Bring extra items needed at stations as extra rulers.

Quick supervisor checklist of useful items to include

stop watches, answer sheets, extra set of questions, tie-breaker sheets, answer keys, highlighter, calculator, extra pencils, red pens, extra mm rulers, stapler, masking tape, scotch tape.

STUDENT PREPARATION TIPS

Avoiding human mistakes and experimental errors

- Be careful to avoid careless human mistakes which are the biggest problem in competition and the most difficult to remember after you have completed the competition.
- Examine the materials and resources provided before attempting to answer questions.
- Use appropriate procedures or techniques when doing a task to avoid systematic errors.

Answering questions

- Carefully read all questions to determine exactly what is being asked.
- Take a moment to determine if your answer makes sense.
- Be certain that you have completely answered each question.
- Pay attention to details in the questions and in your answers.

Team work skills

- Use time effectively! Assign tasks and trust your partner's skills.
- Identify and utilize the strengths of each team member.
- Practice working as a team and perfecting proper techniques and procedures.

Time limits

- Practice under competition conditions.
- Practice effective methods of using the strength of each team member to maximize the use of allotted time.
- Make up sample questions and stations to practice completing tasks correctly and accurately within an assigned time limit.

Measurements and Calculations

- Select the most appropriate type of instrument for the type of measurement requested.
- Be sure to analyze the instrument to determine its capacity (range), increment values, and calibration or adjustment to ensure the proper use of the instrument.
- Make measurements to the accuracy of the instrument.
- Read the increment carefully and record answers to the accuracy of the instrument.
- Be sure to remember any special considerations such as a meniscus.
- Use the same instrument for multiple measurements to improve precision.
- Give your answer in the proper units and be sure to include the units with your answer.
- Be sure calculations are set up and carried out properly.
- Work in a neat organized fashion showing all work where partial credit is possible.
- Be sure your answer is recorded correctly with units and that it makes sense.
- Remember that calculations may be used for breaking ties.

Reference materials

- Review the process skills involved in doing life science labs and designing or evaluating investigations. Also review the identity and appropriate use of common lab equipment.
- Use the training materials available for this event to practice lab station tasks and process skills. There is a training manual, this training guide, and several sample tournaments.
- Review the proper techniques for performing common lab tasks and procedures.
- Use your school's life science textbook and lab manual to help you develop practice lab stations and questions as well as evaluating experimental procedures and design.

MEASUREMENT TIPS

Accuracy is the closeness of a measurement to the true value of what is being measured. The accuracy depends upon the quality and calibration of the instrument being used.

Instruments are supplied with the following information.

Capacity - the amount that can be measured with the instrument.

Range - the high value up to the low value. (Used where zero is not the low value.)

Numbered increments or graduations - the value represented by the numbered graduations or increments on the instrument. Some instruments such as balances may have more than one set of numbered increments.

Unnumbered increments or graduations - the value represented by the unnumbered graduations or increments on the instrument.

Readability - the smallest unnumbered increment on the instrument. The readability is listed on some instruments as balances. It is always listed in the supply catalogs with a description of each instrument.

Vernier scale - a gliding scale to increase the accuracy of the estimation. It is often found on vernier calipers, micrometers, barometers and balances.

Tips

- Choose the appropriate instrument for the requested measurement task.
- Be sure to identify the value of the numbered and unnumbered increments as well as the readability of the instrument before beginning the measurement.
- When measuring liquids in a cylinder or pipet, remember to read the bottom of the meniscus curve.
- When measuring with a metric ruler, be sure that the first increment is present. In some cheap rulers it may not be present or may not be at the very end of the ruler. In this case, begin measuring at 1.0 cm. and subtract 1.0 cm from your reading. *Remember* that the numbered increments of a metric ruler are in cm and the unnumbered increment is mm.
- Remember that beakers are designed to hold liquids and estimate amounts. They were not intended for use as a measurement device.
- When making several measurements, use the same instrument each time for more reproducible results. Be sure to read the instrument carefully to avoid making mistakes.
- On instruments that have sufficient space between the unnumbered increments, it is customary to record the answer one place beyond the value of the readability by estimating the last value. If the space between increments is very small, estimate to the nearest half of the increment.

Measuring Device	Smallest Increment	Record to Nearest
Examples		
metric ruler	1 mm	0.1 mm
grad. cylinder	1 mL	0.1 mL
grad. cylinder	0.2 mL	0.1 mL
grad. cylinder	0.1 mL	0.01 mL
Celsius thermometer	2° C	1° C
balance	0.1 g	0.01 g

- For electronic balance, there is no way to estimate the last value so the answer must be recorded as presented by the balance.
- Be sure to record measurements correctly including proper units.

HUMAN MISTAKES VS. EXPERIMENTAL ERRORS

Human Mistakes are mistakes or blunders made by the person performing the procedure due to carelessness or individual bias. Examples of human mistakes are misreading directions, incorrectly reading a measuring device, using incorrect chemicals or forgetting to include a component, incorrectly measuring chemicals, spilling or contaminating solutions, breaking equipment or using unclean equipment, recording measurements incorrectly or doing calculations incorrectly. Data derived as a result of human mistakes is not valid. If you know you have made a human mistake, the results should not be used. **Many problems in competition result from human mistakes. Human mistakes can be avoided by care and attention to detail when performing a task.**

Experimental Errors are errors resulting from instrument variation or the techniques used to conduct an experiment. There are two types of experimental errors – **systematic errors** and **random errors**.

Random Errors are chance variations due to variations in individual test specimens, difference measuring devices or pieces of equipment, environmental variations, or different persons performing the experiment. These errors will have an equal chance of having results that are too high or too low. If sufficient numbers of measurements are made the low values will cancel out the high. Examples of chance variations or random errors include variation in eye level when reading an instrument, variations in calibration from one instrument to another of the same type, variations in different pieces of equipment of the same type, slight variations in environmental conditions. **The experimenter has little or no control over random errors.**

Systematic Errors are the result of the way in which the experiment was conducted or the design of the system. These errors result in values that are consistently too high or too low. Examples of systematic errors are miscalibrated measuring instruments, improperly adjusted instruments, not noticing a ruler with rounded ends, a clock with runs too fast or too slow, reading the top instead of bottom of a meniscus. **Reducing systematic errors comes with increased skill of the experimenter in refining techniques and checking the calibration of instruments, recognizing and eliminating sources of systematic errors.**

BASIC STATISTICAL ANALYSIS

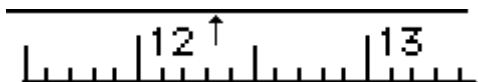
Mean is the average. It is found by adding all of the values and dividing by the total number of values. The mean is used to analyze random error.

Median is the middle value. It is found by arranging all of the values in increasing or decreasing value or magnitude and finding the middle.

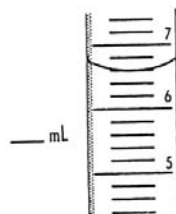
Mode is the value that occurs most frequently or often.

Range is the difference between the high value and the low value.

PRACTICE TASKS



Type of instrument _____ (metric)
 Capacity _____
 Numbered increments _____
 Unnumbered increments _____
 It's reading is _____ c m
 List possible errors or mistakes:



Type of instrument _____
 Capacity _____
 Numbered increments _____
 Unnumbered increments _____
 It's reading is _____
 List possible errors or mistakes:

Yeast Fermentation – 24 Hours Old Culture

Team Number	Length of CO ₂ Bubble
1	58 mm
2	63 mm
3	55 mm
4	80 mm
5	65 mm
6	0 mm
7	50 mm
8	30 mm

Note: 2 drop of yeast were placed in a fermentation tubes containing the same same amount of a 10% molasses solution. The diameter of all tubes were the same.

Identify any possible human errors or systematic errors in the data.

Determine the mean for the length of the carbon dioxide bubble. Show your work.

Determine the median for the length of the carbon dioxide bubble. Show your work.

Determine the mode for the length of the carbon dioxide bubble. Show your work.

Determine the range for the length of the carbon dioxide bubble. Show your work.

I hope these suggestions are helpful. Comments or new ideas are always welcome.

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There is a training manual entitled “Coaches Handbook for Life Science Process Lab” available from the Science Olympiad National Office. It contains lessons for use in the classroom and with your team as well as three sample tournaments.

There are also training manuals for other events and video tapes for many building events. The order form for all training guides and video tapes is available at <http://soinc.org/tguides.htm>