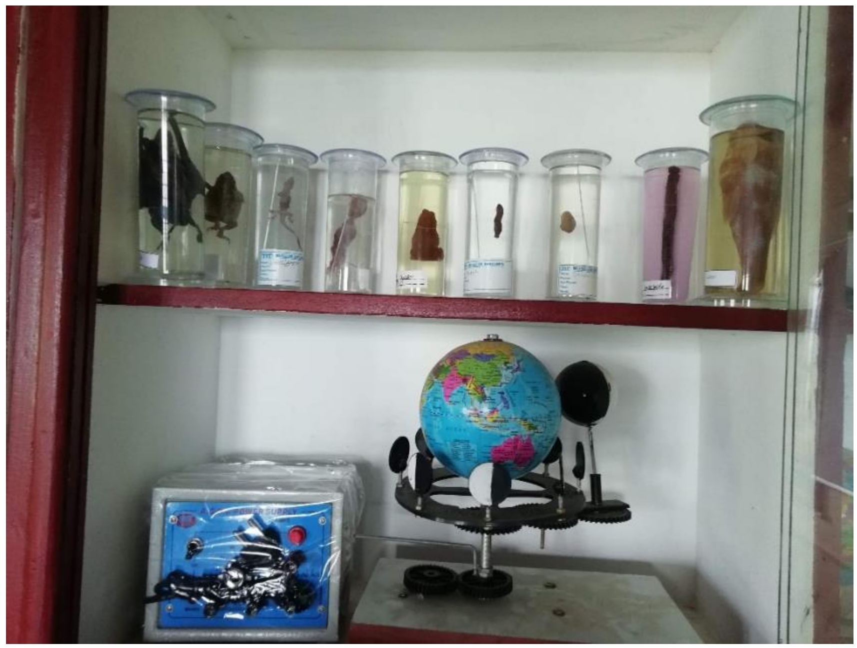
TGUP's Science Lab in a Box
Lab Procedures & Outcomes



TGUP's **Science Lab in a Box** (**SLaB**) is a set of tools, supplies, equipment, and instruments needed to teach sophisticated laboratory science at the high school level anywhere in the world.

Lab Procedures and Outcomes (LPO) is one of the foundational documents in TGUP's **Science Lab in a Box.**

The **LPO's purpose** is to describe each experiment at a level of detail that will allow the instructor to understand what is to be accomplished, and plan his/her laboratory and classroom execution accordingly, so the lab experiences can be successfully integrated into the instructor's and school's overall Science curriculum.

Each entry will also serve to signal to the students what it is they are about to undertake, what they will do, and what they can expect to learn from this experiment. All of the equipment and supplies for every experiment are included in the **Science Lab in a Box.**

Each entry in the LPO includes:

- Title of the experiment
- Description of what is to be done
- An explanation of what is happening in scientific terms
- The defined learnings expected from successful execution of the experiment
- Applications of these learnings in the real world.

TGUP gratefully acknowledges the central part played in the creation of this LPO by the Science faculty at Los Altos High School, Los Altos, CA. Feedback welcomed.

BIOLOGY EXPERIMENTS

1. DNA Extraction	Students extract DNA from fruit using mechanical and chemical techniques. This laboratory involves making solutions and using solvents along with physical forces to break apart plant tissue and “purify” and remove DNA from solution. Students will need to consider which cellular organelles are affected by the physical forces, solutions and solvent as these organelles are removed to liberate the DNA housed in the nucleus. Careful adherence to protocol is key to success with this activity.
2. Classifying Cells by Kingdom Found in a local body of water.	Students compare & contrast cells representing different kingdoms collected using plankton nets from a natural water source. Students will directly observe similarities and differences between cells of members of the different kingdoms by utilizing skills with sample collection, microscope slide preparation, and proper use of a compound light microscope. Students will learn about how dichotomous keys are used to classify living things in the biosphere. They will also learn more about the structure of a generalized eukaryotic cell.
3. Solute Concentration Effect On Cells	Students will vary concentrations of solute to determine the approximate molarity of a vegetable. Students will need to carefully adhere to protocol. Students will develop skills related to preparation of solutions of varying concentrations. This will involve basic stoichiometry. Students will collect initial and final masses of plant tissue exposed to different molarities of a sugar solution and use spreadsheets to perform the necessary analyses. Doing so will allow them to determine the approximate molarity of the plant cells under study. The concepts of passive transport, osmosis, and tonicity are also reinforced with this laboratory investigation.
4. The Cell Cycle	Students observe plant cells in different stages of the cell cycle. Students continue developing skills with microscopy. Students apply basic mathematics to raw data sets consisting of counts of cells in different stages of the cell cycle. Students will develop a better understanding of the stages of the cell cycle and mitosis. They will also have the opportunity to consider when and where it isn’t appropriate for cells to move through the cell cycle, what the cell cycle does for unicellular and multicellular organisms. They will also learn about cell cycle control systems and cancer.

5. Photosynthesis	Students submerge sprigs of freshwater plants and measure oxygen release as a function of distances from a light source. Students obtain counts of bubbles at various distances over time and determine a rate. This can be performed with spreadsheets. Students learn about the light reactions of photosynthesis and how oxygen is produced as water is split during these reactions. Students can observe the effect of environmental factors on photosynthetic rate and consider ecological implications.
6. Fermentation	Students will determine the rate of fermentation by yeast as a function of sugar concentration. Students will observe fermentation occurring by measuring the rate of carbon dioxide production. There are a variety of means to do this subjectively (balloon inflation, foam production). As students make their subjective observations (teachers are welcome to engineer a simple respirometer using a larger and smaller test tube if quantifying is desired), they will apply their knowledge of the metabolic pathway of alcoholic fermentation to explain the gas production. Students will continue to hone their observation skills, following a protocol, data collection, etc.
7. Bacterial Growth	Students will culture bacteria from different environments comparing and contrasting the growth observed from the swabs of each environment. They will do this by visiting different sites on their school campus and apply the same collection protocol for different surfaces of their choosing. They will learn that a microscopic world is thriving all around them. They will have the opportunity to learn about their own symbiotic relationships with microorganisms. This can also be useful as an introductory activity to measuring and documenting biodiversity. Students will develop a number of skills including culturing techniques. Microscopy can also be utilized here.
8. Natural Drug Discovery	Students extract compounds from a variety of plants to determine their antimicrobial properties. Students make extracts, soak paper discs in the extract and place them on a petri dish that has been cultured with bacteria (or other microorganism). Students will then observe if zones of inhibition (areas of little to no growth) form around the discs. If a zone exists, this indicates the extract has antimicrobial properties. Students learn about different plant compounds, drugs can be derived from other living things, and one of the

	services of biodiversity is as a reservoir for these compounds. There are evolutionary connections to be made and that habitats must be preserved. Students will have to perform research to determine appropriate solvents for extractions, culture microorganisms, and adhere to protocols.
9. Food Web Using Owl Pellets	Students dissect an Owl Pellet and Identify the prey species. Students are provided owl pellets (a bolus of indigestible material like fur and bones) and break the pellet apart carefully in an attempt to identify what the owl may have eaten. Students should be able to reconstruct portions of the prey item skeletons. Students learn about predator prey interactions, trophic levels, and energy flow and nutrient cycling in food webs. Observation, tactile skills, analyzing when piecing the prey back together.
10. Water Quality Testing	Students look to a local freshwater source and measure pH, dissolved oxygen, nitrate, and ammonia levels to determine the health of an aquatic ecosystem. They will use a variety of water testing kits to do this. Students will follow the protocols for each testing kit. Students will learn sampling techniques and can also learn the chemistry behind the ability of the various kits to detect nutrient concentrations and pollutants. Students will learn what is needed to maintain healthy aquatic ecosystems and how human impacts can adversely affect them. Students will learn the mechanics of water quality testing.

CHEMISTRY EXPERIMENTS

1. Mass, Volume and Density	Students will learn the technique of calculating the volume of both a regular (metal rod) and irregular object by water displacement. Furthermore, they will utilize the formula for the volume of a cylinder to assess their water displacement technique. The crucial skills learned are determining mass using a balance and measuring volume with a graduated cylinder.
2. Identifying Iron Cations	Iron is an important nutrient for the human body. But it comes in three forms (Fe^{o}, Fe^{+2}, Fe^{+3}), and it often confuses students. This lab utilizes chemical spot tests to determine what oxidation state of iron is present in common foods and substances.

3. Products Of Combustion	When studying energy and global climate change, students learn how to recognize, balance, and calculate the energy from the following equation: Hydrocarbon (Fuel) + $O_2(g) \rightarrow CO_2(g) + H_2O(g)$ But students often ask how do we know these products are being formed? How did scientists long ago detect carbon dioxide and water vapor? Afterall, they are both clear, colorless gases with no smell. Students will design a simple apparatus with a candle and a jar and use some simple chemicals to detect the presence of water. Homemade $CoCl_2$ strips will turn from blue to pink in the presence of water and carbon dioxide will produce a noticeable precipitate when reacted with limewater (dilute $Ca(OH)_2$ solution).
4. Chemical Reactions: Stoichiometry & Limiting Reagents	Does 1+1 = 2? Does 2+1= 3? In math maybe, but not always when you are balancing chemical reactions. Students utilize a set amount of vinegar (acetic acid) and increasing amounts of baking soda (sodium bicarbonate) to fill up 2-Liter soda bottles (topped with balloons) with carbon dioxide. Students make predictions on the size of the balloons and are surprised when their predictions are incorrect. Important skills learned are stoichiometric calculations and a better conceptual understanding of limiting reagents and percent yield. This lab is also great for teaching types of reactions as well. Big picture, this is an acid-base reaction but can also be taught under the guise of a double replacement reaction. Furthermore, the carbonic acid formed is unstable, and undergoes a decomposition reaction to produce carbon dioxide and water.
5. The Universal Gas Constant.	The universal gas constant lab requires students to collect hydrogen gas from a chemical reaction of magnesium and hydrochloric acid. By utilizing a special tube (eudiometer) they will measure the volume of the gas collected. Measuring the temperature, and pressure in the room, students can utilize the moles of magnesium reacted to solve the ideal gas law for the universal gas constant (0.0821 L atm mol^{-1} K^{-1}.) Students will learn the concepts of gas properties, how a barometer works, Dalton's Law of Partial Pressure, and limiting reagents.
6. Specific Heat of Metals	Using a simple coffee cup calorimeter (nested styrofoam cups), students will use various heated metal rods to determine the identity of those metal rods. The equation, $q_{(H2O)} = q_{(rod)}$

	or $m_{(H2O)} \times c_{(H2O)} \times \Delta T(T_f - T_i) = m_{(rod)} \times c_{(rod)} \times \Delta T(T_f - T_i)$ will be utilized to determine the specific heat of the rod. With this information, students can determine what the unknown metal is. With a slight modification, students can attempt to determine the metal composition of various coins.
7. Acid-Base Titration	The acid-base titration lab requires students to determine the molarity of a NaOH solution using a known concentration of hydrochloric acid. Students learn to neutralize a reaction, to visualize a reaction's endpoint, to utilize a titration curve and the practical uses of acid-base indicators. Applications of titration are used in food, cosmetic and pharmaceutical industries as well as in biodiesel manufacturing and medical diagnosis.
8. Artistic Anthocyanins: Acid-Base Painting	Art and science are sometimes viewed as opposing subjects, but are united in many ways. Pigments for art are usually synthetically produced, but nature produces many environmentally friendly colors for your paint palette. In fact one pigment, anthocyanins from red cabbage, can turn many different colors depending on the pH of the solution it is in. Students will paint with acids and bases on various media soaked in red cabbage juice. Student will learn the benefits of using natural pigments, learn how colors can be manipulated, explore how using different media can affect and individual's artwork, and gain an understanding of indicators in acid-base chemistry.
9. Freezing Point Depression	Inhabitants of northern or mountainous regions are familiar with winter and the snowy, icy roads that result. Road crews spread various chemicals on the road in order to lower the temperature at which freezing occurs. In this lab students will add various chemicals (NaCl, $CaCl_2$, $AlCl_3$, and sucrose) to ice and record the lowest temperature. Students will then use this data to develop a theory as to why certain chemicals lowered the temperature more than others. By utilizing the freezing point depression equation, $\Delta T_f = K_f \times m \times i$, students will learn how to calculate and understand the Van't Hoff Factor. This lab reinforces the idea of dissociation of ionic compounds into ions, reinforces stoichiometric understanding, and teaches students the concept of colligative properties. The idea that some properties rely on the amount of a chemical, not its identity. This lab has an interesting historical perspective to it as well. The

	story of the Wild Ionists can teach students that sometimes the “experts” are wrong and you need to always trust your data and your heart.
10. The Effect of Concentration on Reaction Rate	Students will utilize the precipitation reaction of sodium thiosulfate, $Na_2S_2O_3$, with hydrochloric acid to study the effect of changing concentrations on reaction rates. Students will be given an initial event to accomplish, timing how long it takes a smiley face to disappear at the bottom of a beaker after adding the two reactants. The students will then design their own experiment(s) to determine whether the rate of this reaction is dependent on sodium thiosulfate or hydrochloric acid.

PHYSICS EXPERIMENTS

1. Free-Falling Projectiles	The free-falling projectiles lab is designed for students to apply constant acceleration kinematics concepts to a horizontally launched projectile. Students will measure, record and graph initial vertical launch heights and horizontal distance values to predict projectile launcher's initial speed. Students will model an apex to ground free falling projectile with a horizontal launch velocity and plot the height vs. range data to form a line with a slope equal to the launch speed. To verify their launch speed measurement is correct, students will reposition the launcher at an angle above the horizontal, predict the location of the apex and attempt to hit a target. Students can also use the data to measure the acceleration of objects in free fall near the surface of the Earth.
2. Newton's Laws In Equilibrium	The Newton's laws in equilibrium lab is designed for students to apply Newton's laws of motion using vector decomposition concepts to a two dimensional force system. Students will predict equilibrium conditions and verify their predictions using a force table. The force table is a large, circular protractor with several strings pulling on a central metal ring. The lab apparatus helps students connect the abstract force vector decomposition to their concrete visual observations.
3. Circular Motion	The circular motion lab is designed for students to experience how a constant centripetal force can result in a variety of combinations of circular radii and speeds. Students will use a small low friction cylinder, a length of string and a small amount of mass tied to each end. The lab requires students to measure length and time, then calculate speed and centripetal acceleration. Students

	discover and gather evidence that constant centripetal acceleration can take many different forms.
4. Work & The Conservation of Energy	The work & conservation of energy lab is designed for students to investigate the work done by gravity and friction in rolling a ball down a ramp then free falling towards the ground. Students will predict and verify the mathematical relationship between the ball's height on the ramp and height above the floor compared to the horizontal range during free fall. Students will also indirectly measure the energy lost to sound and heat during the process. The principle of the conservation of energy is used by physicists and engineers ranging from quantum mechanics to cosmology.
5. Simple Harmonic Oscillators	The simple harmonic oscillator lab is designed for students to perform several different experiments using both a simple pendulum and a mass - spring vertical oscillator. Using a simple pendulum, students can determine the mathematical proportionality between oscillation period, string length, amplitude and mass. By plotting a graph of $4\pi^2L$ vs T^2 , students will measure the strength of the gravitational force field near the surface of the Earth as the slope of the resulting line. Using a mass - spring vertical oscillator, students can determine the mathematical proportionality between oscillation period, mass, amplitude and spring constant. The study of oscillators helps develop concepts used to describe the transmission of energy using light and sound waves.
6. Impulse & The Conservation of Momentum	The impulse and momentum lab is designed for students to investigate the relationship between forces on a low friction dynamics cart during a collision with an elastic band and the change in the cart's velocity. Students will use force and motion sensors to collect impulse and velocity data before, during and after the collision. The data can be analyzed to predict the mass of the cart, verify the impulse momentum theorem and determine if the collision is elastic or inelastic. The study and understanding of impulse and momentum are fundamental in further study of thermodynamics, automotive safety engineering, particle physics and astrophysics.
7. Wave Interference and Resonance	The wave interference and resonance lab is designed for students to measure the speed of sound in air. Students use tuning forks to send sound waves into hollow tubes while changing the tube's length and listening for resonance. Measurements of frequency, tube length and harmonic number are recorded. Students observe

	concrete evidence of wave interference and make an accurate measurement of the speed of sound. This lab helps students recognize the power of mathematical modeling in science and is a hands on - ears on exposure to wave interference.
8. Electrostatics, Ohm's Law & Circuits	The circuits lab is designed for students to experimentally discover the patterns of electric current through and voltage across Ohmic resistors wired in series and parallel. Students will then use multimeters and equivalent resistance circuit reduction theory to predict and then verify current, resistance and voltage for resistors and capacitors wired in combinations of series and parallel. Ohm's law circuit theory is the foundation of electric circuits and modern electrical devices.
9. Magnetic Fields and Forces	The magnetic fields and forces lab is designed for students to investigate the strength of a permanent magnet's force field as a function of distance and investigate the creation of electromagnetic fields using current through a solenoid. Students will create a solenoid by wrapping a long, thin, insulated wire into small circular coils and connecting each end to the speaker output connections of a music boombox / CD player. Then by securely taping the coils to a paper cup or index card and bringing a permanent magnet near the solenoid, students will feel the effect of the magnetic forces and hear the music playing through their homemade speaker. Applications of magnetism include electromagnetic wave transmission and reception, electromagnetic mechanical devices, medical imaging devices and the generation of electricity using electromagnetic induction turbines.
10. Geometric Optics - Mirrors & Lenses	The mirrors and lenses labs are designed for students to investigate the use of ray diagrams and the mathematics of mirror and lens equations to predict image characteristics formed from objects shining light towards plane and curved mirrors and lenses. Students will use plane mirrors, LED lasers, protractors and rulers to predict the path of light using the law of reflection to strike a target. Students will use ray diagrams, mirror and lens equations to predict image location and characteristics, then use curved mirrors and lenses to create images and verify their predictions. The study of optics has applications to communications, astronomy and biological sciences.

SLaB EQUIPMENT LIST

Biology Equipment	Chemistry Equipment	Physics Equipment
400x Compound Microscope	Bunsen Burner w/ Sparker	Projectile Launcher
Slides & Cover Slips	Hot Plate w/Magnetic Stirrer	Force Table
Iodine	Density Blocks	Loop-the-Loop Track
Bromothymol Blue	Eudiometer Tube	Multimeter
Prepared Microscope Slides	Burette	Circuit Breadboards
Dissection Kits & Trays	Calorimeter	Resistors & Capacitors
Forceps & Scalpels	Alcohol Thermometer	Mirrors & Lenses
Petri Dishes	Molecular Modeling Kits	Electroscope & Pith Balls
Inoculating Loops	Copper (II) Chloride	Prisms
Nutrient Agar	Ammonium Hydroxide	Hooke's Law Springs
Filter Cloth	Hydrochloric Acid	Mass Sets
Photosynthesis Light Source	Phenolphthalein	Diode Lasers
Owl Pellets	Litmus Test Paper	Water Bottle Rocket
Water Quality Testing Kits	Acetic Acid	Electromagnets
Plankton Nets	Deionized Water	Permanent Magnets
Modeling Clay	Magnesium Ribbon	Doppler Effect Demo Device
General Lab Equipment		
Ring Stands	Electronic Balances	AC / DC Power Supply
Safety Glasses	Beakers	Meter Sticks
Safety Eye Wash	Erlenmeyer Flasks	Metric Tape Measures
Chemical Safety Aprons	Graduated Cylinders	Stop Watches
Ring Stand Clamps	Funnels	Bicycle Air Pump
C-Clamps	Test Tubes	Metric Spring Scale
Scientific Calculators	Micro Spatulas	Human Weight Scale
Protractors	Wash Bottles	Batteries
Glass Stir Rods	Pipettes	Nylon String & Duct Tape