

## **Art of Experimental Design Teacher Information**

### **ART OF EXPERIMENTAL DESIGN SCHOOL PROGRAM**

#### **WHAT TO EXPECT**

The Vancouver Aquarium's Education Classroom offers students an opportunity to observe and handle live animals, participate in hands-on activities and watch animal-based demonstrations. Students participate in all of these activities with the help of trained Volunteer Educators.

During this experimental design program, students explore the central components of the scientific method and learn the correct procedures for designing a sound scientific experiment. During the rotation through different stations, students' learning is enhanced through the use of live animal experimental demonstrations. In a hands-on activity, students are given the opportunity to apply what they have learned by designing their own scientific experiment and testing their hypotheses using live shore crabs.

The self-guided exercise sheets included in this package are designed to guide the students through the program material and encourage them to rely on their own observations as a means of learning and discovery. These Lab Sheets provide a reference for future experimental design-related investigations and allow the students to review their experience after completing their Art of Experimental Design School Program at the Aquarium.

*The Art of Experimental Design School Program provides an exciting, educational experience which complements the learning outcomes of the B.C. Ministry of Education's Integrated Resource Packages.*

The general objectives of the program are to:

- introduce the students to the basic principles of the scientific method, experimental design and critical thinking.
- explore the methods of correct hypothesis formation and the importance of having a controlled experiment.
- provide students with the tools to critically examine scientific claims in various media presentations.
- allow students to apply their knowledge and creativity in designing their own controlled experiment: forming a hypothesis, setting up experiment, recording data and presenting findings.
- foster a sense of interest in scientific investigation and research by providing students with the opportunity to observe interactions with living marine organisms.
- provide an inspiring, educational experience that complements the applications of sciences and the processes of biology component of the B.C. school curriculum for grades 8 – 12.

## **Art of Experimental Design Teacher Information**

### **WHAT YOUR CLASS WILL DO AT THE AQUARIUM**

#### **Introduction**

An Aquarium Educator welcomes your students to the Aquarium and introduces the program theme and agenda.

#### **Stations**

Volunteer Educators lead small groups of seven to ten students through three stations based on key components of the scientific method. Worksheet handouts are provided to guide your students in their observations and to give them a place to record their discoveries.

**HYPOTHESIS FORMATION:** Students learn how to form a hypothesis and apply these skills directly through an activity using a sea cucumber, sunflower star, bat star and sea urchin.

**THE IMPORTANCE OF A CONTROL:** Through observing a reaction using sea scallops and a sunflower star, students learn the importance of conducting *controlled* scientific experiments.

**EXPERIMENT REPLICATION:** Students learn about the significance of having many experimental trials in order to increase confidence in their resulting data. Activity involves a hands-on sea urchin experiment.

#### **Student Experiments Applying the Scientific Method**

In groups, students are assigned an experimental inquiry and encouraged to apply what they have learned during the program to design their own controlled experiment. With the guidance of the volunteer educators, students will set up an experiment, work with live shore crabs to test their hypotheses, record their results and present their findings to the class. The coordinator will conclude the program with brief discussion on the different group experiments and an opportunity for final questions and answers.

#### **Critical Thinking, Conservation and Wrap-Up**

An open discussion about a conservation topic is begun and students are introduced to critical thinking. Students are introduced to some tools that are useful in critically examining scientific claims in various media formats: scientific journals, advertisements, newspapers. Students are encouraged to use these critical thinking tools to analyze different types of media and form their own opinions.

#### **Total Time of Program**

2 hours

#### **Before or After the Program**

You and your class are welcome to visit the Aquarium's galleries at no additional charge.

## Art of Experimental Design Teacher Information

### BACKGROUND INFORMATION

#### Scientific Method

The scientific method is a process for experimentation that is used to explore observations and answer questions. Scientists use the scientific method to search for **cause and effect** relationships in nature.

The scientific method has a few easy steps: observe, hypothesize, experiment, conclude and apply. Observations are made by scientists and meticulously recorded as text, drawings or pictures/videos. A hypothesis is put together that might explain something from an observation. The hypothesis predicts an outcome, is in the form of an if/then statement and is testable. An experiment needs to be designed that will isolate the variable of interest to the scientist. The experiment needs to have a treatment (with variable of interest) and control (without variable of interest) that can be compared with each other. Then, the experiment needs to be replicated to increase confidence in the results. Finally, the scientist accepts or rejects their hypothesis, interprets their findings and finds ways to apply them.



#### Vocabulary

**Control**-the part of an experiment which is the same as the treatment in every way except for the factor being tested. Controls are used as a comparison point for the experimental treatment.

**Experiment**-a situation where one or more factors are varied by a researcher in order to test the effects of the factor on one or more subjects.

**Manipulative experiment**-an experiment in which the factors are varied by the researcher according to a preconceived plan in an artificial set up.

**Mensurative experiment**-an experiment in which the researcher compares two or more already existing subjects which appear to differ only in the factor being tested.

**Experimental Design**-the preconceived, systematic framework in which the effects of factors on subjects are tested.

**Factor**-The item which a researcher believes will have an effect on the subject. See also independent variable

**Hypothesis**-a conjectural proposition set forth as an explanation for a specific phenomenon or observation

## **Art of Experimental Design**

### **Teacher Information**

**Null hypothesis**-a re-statement of the hypothesis which assumes that factor of interest has no effect on the subject. This is tested by the experiment and accepted or rejected on the basis of the results.

**Pilot Study**-a small-scale study run before a major study, used to evaluate the experimental design.

**Replicate**-the repeated unit of each treatment and control in an experiment

**Sample**-a subset of the population under study.

**Random sampling**-sampling in a manner such that the selection of one sample has no effect on the selection of any other sample. In random sampling, all units in the population have an equal chance of being sampled.

**Systematic sampling**-sampling according to a predetermined and systematic plan. The population units are sampled at regular intervals or multiples thereof.

**Subject**-that which the researcher believes may be affected by a factor. See also dependant variable.

**Theory**-an explanation of a phenomenon or observation which is based on all known facts concerning that phenomenon.

**Variable**-a characteristic which takes on different values for different individuals or measurements.

**Dependent variable**-the variable, in an experiment, that is assumed to be being affected by the independent variable. See also subject.

**Independent variable**-the variable, in an experiment, that is assumed to affect the dependant variable under study. See also *factor*.

## Art of Experimental Design Teacher Information

### Sea Stars/Sea Cucumbers/Sea Urchins

Phylum Echinodermata; "echino"= spiny; "dermata"= skin

Sea stars, sea urchins, sea cucumbers, and other related spiny-skinned invertebrates share a basic body plan of five identical sections that surround a central mouth. Most echinoderms can move and manipulate food by extending or contracting hundreds of tiny, muscle-bound cylinders of water, called tube feet. Sea stars also owe their formidable staying power to these suction-tipped tube feet, which you will have experienced if you have ever tried removing one of these animals from a rock. Be gentle if you are handling sea stars as you can easily tear off an animal's tube feet! As well, watch out for the eyespot at the end of each arm of the sea star.

#### **Sunflower Sea star** (*Pycnopodia helianthoides*)

Students may say 'starfish': let them know that this term is not really used anymore. Since these animals don't look like fish and have very little in common with them, we now use the term 'sea stars'. Sea stars belong to the phylum *Echinoderms* (meaning 'spiny skin')

The sunflower star is a carnivore that feeds on a variety of invertebrates including bivalves, gastropods, chitons, crabs, sea cucumbers, sea stars and dead animal matter. Its favourite food is the purple sea urchin. It hunts its prey in deep water and in low intertidal pools (range: Alaska to California).

*This sea star is a quick and voracious predator for 3 main reasons:*

- It can grow quite large - up to one meter across (probably the largest known sea star in the world);
- It can have up to 26 arms to grab on, and;
- With so many arms, it can have more than 15,000 tube feet, and therefore can move up to 3 m per minute (very fast for an invertebrate).

#### **California Sea Cucumber** (*Parastichopus californicus*)

This sea cucumber has prominent, cone-shaped spines (sea cucumbers also belong to the phylum echinoderms). These may look nasty, but have the students touch them: they are soft! Only 'fake



spikes'. The sea cucumber can reach a length of 40 cm, and lives on protected rocky shores, in the sub tidal zone (that's below the low-tide line), from Alaska to Baja California. Cucumbers feed on detritus (particles/ sediment) and small organisms that they gather with their 10 to 30 oral tentacles (what looks like 'feathery arms' coming out of the mouth). They can slowly crawl on the substrate with the tube feet (on their ventral side), or they can move quickly, in a worm-like fashion, by using 5 long muscles inside their body. To escape predators, they can also EVISCERATE: eject their stomach/ 'spit out their gut', which will re-grow after a while. The tube feet also act as sensory organs. And no, sea cucumbers don't have

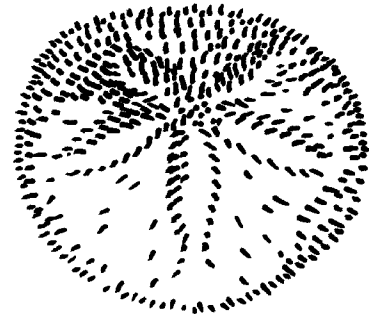
## Art of Experimental Design Teacher Information

eyes...but don't tell your students right away: let them hypothesise, and figure out why it's important to make an educated guess – and not just any guess!

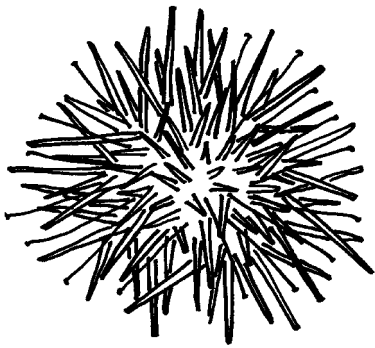
In Puget Sound, natural populations of the California Sea Cucumber normally eject their internal organs in late fall and then regenerate a new set for spring. They are currently the only species of sea cucumber harvested in BC - only every three years to control population decline. They are eaten for their muscle strips and body wall.

### **Green Sea Urchin** (*Strongylocentrotus droebachiensis*)

The green sea urchin is one of the most widely distributed Echinoderm. They are found in both the Atlantic and Pacific oceans extending all the way up to the arctic regions. It commonly inhabits the shallow rocky sub tidal zone, but can be found at depths of up to 300m.



Green sea urchins are omnivorous (You can ask students if they know what that means...eats plants



and animals). They eat kelp as well as muscles, dead fish/squid, clams... however the urchins primarily graze on kelp – *Lamairia* spp. – due to its abundance and availability as opposed to shellfish and other animals (do not mention this because we will cover it in the group discussion of our results!)

A variety of predators eat green sea urchins including crabs, sea stars, wolf eels, sea otters and humans. Humans consume the sexual organs called "roe" either raw or slightly cooked. Sea urchin roe is popular in Korean cuisine and is called 'uni' when used in Japanese sushi. In some traditional cultures, sea urchin roe is considered an aphrodisiac.

Sea urchins have separate sexes. They reproduce by external fertilization releasing their gametes into the water column. You may notice a white milky substance oozing from the top an urchin – it is releasing sperm. The eggs are also released from the opening on the dorsal surface (the anus) look like little round orange balls. After fertilization the resulting larva lives in the plankton for 1-4 months before settling to the sea floor and metamorphosing into an adult form. In the wild, reproduction occurs annually, usually in the spring between February and May.

Where urchins occur at high density, destructive grazing can produce habitats devoid of seaweeds. These areas may be termed "sea urchin barrens." When sea urchins are removed from these sites, either manually or by disease, the reduction in grazing pressure often results in the development of highly productive kelp forests. These kelp beds provide shelter for a wide variety of marine organisms (e.g. fish, lobsters, crabs, sea stars, bivalves, gastropods, bryozoans) and the habitat is typically much more diverse than barren grounds. Hence, sea urchins are one of the principal factors controlling habitat diversity in the rocky sub tidal environment.

## Art of Experimental Design Teacher Information

Ask students to look closely at the urchins. What do they notice? (They usually say "spines" first) Why do you think they have spines? (For protection or movement) Take a close look and notice the spines are moving – they have muscles along the inside of the test that attach to the spines and contract/relax to move them. What else do they notice? (They might say "moving sucker tentacle things") These are tube feet! Tube feet are used to help move around and capture food. They have little sucker on the ends, and they are able to suction to things by means of their water vascular system (a system that brings in water and releases it to create suction). Note: all echinoderms have tube feet.

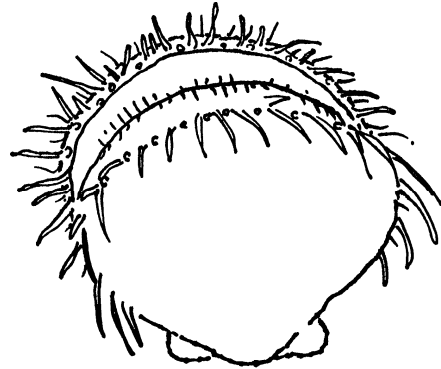
Where is the mouth of the sea urchin? The mouth is located on the underside in the middle. It consists of a complex array of skeletal elements, plates, and teeth arranged in five symmetry called the "Aristotle's lantern." Pass the display Aristotle's Lantern around. The mouth leads to the digestive tract, which empties through the anus located on the top of the test. Sometimes you will notice little round things coming out the top of the urchin. This is either excrement (small round brown balls), eggs (round orange balls), or sperm (milky substance).

### Swimming Scallops (*Chlamys* sp.)

Phylum Mollusca (MOLL-us-ka); "moll"= soft

Just present them as 'scallops', otherwise you'll be giving away part of the show!

Scallops are molluscs (class *bivalvia*: meaning 'two shells'). Most bivalves live buried in the sand or attached to the substrate. This particular species of scallop can 'swim' by rapidly opening and closing its valves, it forces water in and out: like jet propulsion. This is mainly an evasive response triggered by the presence of a predator (especially sea stars), but it can also be the result of other factors. This movement demands a lot of energy from the animal, so please keep that in mind while doing the experiment (or the last group at this station may not get a very good reaction).



The two valves are held closed by the adductor muscle: that is the part we eat (a chewy, white disc). When the adductor muscle relaxes, the hinge - the two ligaments on each side of the umbo (the pointy end) and the oldest part of the shell – will pull the valves open (which is why an empty shell remains opened and bounces back to this position when we try to close it).

Scallops feed and breathe by filtering the water through their body. The small tentacles along the edge of the valves, also called 'labial palps', are chemoreceptors; sensory organs that can detect smells/ tastes in the water. Also

## Art of Experimental Design Teacher Information

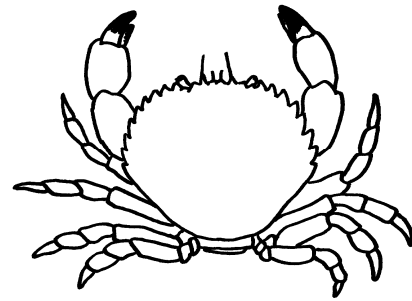
along the edges of the valves, in the mantle, are rows of shiny, black dots: these are the *ocelli* (singular: ocellus), or the eyes of scallop. These eyes are photoreceptors: sensitive to light. In reality, scallop eyes are much similar to human eyes (with a cornea, lens, and retina), however, the scallop doesn't have the 'brainpower' to process the complex information transmitted by such eyes.

The molluscs are a diverse group of more than 100,000 species of living animals, including clams, snails, limpets, sea slugs, octopuses, squids and abalone. Most molluscs can be identified by three features: a large muscular foot, hard shells they create to cover their soft bodies, and a toothed, rasping tongue, called a radula (rad-YOU-lah). Octopuses and squids have deviated from the general mollusc body plan. In both of these animals, the foot has evolved into several many-suckered arms. Although neither octopuses nor squids have shells, the squid has a stiff internal rod, called a pen. Both octopuses and squids have a hard, bird-like beak that they use to bite prey.

### **Green Shore Crabs (*Hemigrapsus oregonensis*)**

Phylum Arthropoda, "arthron"= joint, "podos"= foot

These shore crabs are also known as yellow shore crabs, hairy shore crabs, mud flat crabs and Oregon shore crabs. This species grows to about 5cm (shell/carapace) and is found in the intertidal zone from Alaska to Mexico. They can be dark or grayish green, but white or mottled patterns are common. They lack purplish-red spots on pincers and their legs are hairy. They seem to prefer sandy, muddy and gravelly beaches that are quiet and protected areas.



These shore crabs feed by scraping up diatoms and cutting algae, catching smaller invertebrates and by filter feeding, when necessary, by using its third maxillipeds (located on its carapace). It also scavenges for food. This crab along with *H. nudus* is found in abundance throughout the Puget Sound.

# **Art of Experimental Design Teacher Information**

## **PRE VISIT ACTIVITIES**

### **1. Research and the Media**

#### **Summary**

Students look for scientific references in the media and think critically about the way in the media puts its own “spin” on the information.

#### **Objectives**

- To find scientific references in the media
- To critically analyze how the media shares information with its readers
- To determine if an information source is reliable

#### **Steps**

- Have your students find a scientific reference from different media sources (i.e. newspaper, magazines, television, radio)
- Have your students address the following issues in a report and/or as a discussion group:
  - What kinds of scientific research are found in the popular media?
  - What kind of scientific research would the students like to be informed about (what would they like to see reported)
  - How did the different sources approach the information (did they put a “spin” on it so they could sell something?)
- Have your students find and read a paper from a scientific journal. It can be discussed as a post-visit activity.

## **Art of Experimental Design Teacher Information**

### **2. What is a Hypothesis?**

#### **Summary**

Students will make observations of nature and learn how to ask questions in a scientific manner, by making a hypothesis.

#### **Objectives**

- To observe and record your observations of something in nature
- To learn how to formulate a scientific hypothesis that can be used for conducting a scientific experiment

#### **Part I: Slideshow**

Show your class a PowerPoint slideshow or video of animals in nature. Talk about the different behaviors of animals and why they might be used. Describe the relationship between the animals and their environments. Ask the students questions about animal behaviour in order to warm up their thinking caps.

#### **Part II: Go Outside and Observe Nature**

Find a nice place at or near your school where students can find some animals to observe.

#### **Instructions for Students**

- Take a notebook and pen or pencil outside and find a living creature to observe.
- Watch the animal for five minutes and record its behavior (swim, walk, feed, mate, etc.).
- Describe how the animal moves in its environment and describe where it lives using words and pictures
- Write down any questions you may have about the animal
- Draw a picture of the animal when you are done observing it

#### **Part III: Formulate a Hypothesis**

Review the definition and conditions of a hypothesis. A hypothesis is a tentative statement of an educated guess regarding an observation. In other words, it is an educated guess about how something should work. A hypothesis should meet these other conditions: 1) it should be in the form of an If/Then statement (If I do *A (your guess)*, then *B (a consequence)* will happen), and 2) it should be testable. You should probably go over some examples ("an unhappy dog" is not testable).

#### **Instructions for Students**

- Review the definition and conditions of a hypothesis with your teacher
- Use your questions from your observations in nature and write your own hypothesis
- Make sure you meet all the conditions of a hypothesis
- Share your hypothesis with your class and modify it if recommended

## **Art of Experimental Design Teacher Information**

### **3. Experimental Ethics**

#### **Summary**

Students will look for different organizations who use animals for experiments and decide on how and when to use those animals. Check your local labs and the Aquarium.

#### **Objectives**

- To discuss the ethical use of animals in experiments
- To familiarize students with research programs at the Vancouver Aquarium

#### **Instructions for Students**

- Make a list of different organizations that use animals in scientific experiments (you may find some that do experiments on humans!)
- Address the following issues in a discussion of the ethics of experimentation using live animals:
  - When is it ethical to experiment on live animals?
  - How do we (as a community, as scientists) decide which experiments are worth doing?
  - How do we benefit from experimentation (both past and present) on live animals?
  - If we did not use animals for experimentation, how could we do medical and other research (for conservation management)?
- Is animal research necessary for habitat/species preservation?

## **Art of Experimental Design Teacher Information**

### **POST VISIT ACTIVITIES**

#### **4. Scientific Experiment Poster**

##### **Summary**

Students work in pairs to write up their experiment at the Aquarium as a poster. Each poster must include background information on the animals used in the study and a description of some of the things that influence the animals' daily lives (light, temp, water, etc.). The poster should also include their hypothesis, their experimental design and methods, their results and their conclusion. Students can use pictures and graphs to make their posters more reader friendly.

##### **Objectives**

- To review the steps involved in conducting a scientific experiment
- To represent and interpret information in textual and graphical form

##### **Instructions for Students**

- Review your visit to the Aquarium with your classmates
- Review the steps involved in conducting a scientific experiment: making an observation, writing a hypothesis, conducting an experiment using a control and replication, and accepting or rejecting your hypothesis
- Review the experiment you conducted with shore crabs
- Go to the library and get some background information on green shore crabs (*Hemigrapsus oregonensis*): where is it found (including range and distribution), is it active or inactive, how is it adapted to its environment, what does it eat, what eats it, what conditions does it prefer, and include any other information you find interesting
- On separate pieces of paper, nicely print the following: background information on shore crabs, your hypothesis, experimental design and methods, results, and conclusions.
- Add pictures, drawings of your animal and experimental design as well as graphs and tables of your data to make your poster more complete
- Present your poster to the rest of the class

## **Art of Experimental Design Teacher Information**

### **5. Conservation Discussion**

#### **Summary**

In this activity, students role-play different points of view on a “hot” conservation issue. Students give their opinion on what is an important conservation issue and decide as a class which one to “discuss”. Students have a short discussion that brings up a few different points of view and then are assigned groups to represent those different views. Students work in groups and will conduct background research through interviews, internet and magazines to formulate a sound point of view for their role. Students will then have a discussion/debate about the different points of view on the conservation topic.

#### **Objectives**

- To work in a group environment and conduct research on a current event
- To assimilate information from many sources into one cohesive point of view
- To listen to peers and consider an alternate point of view on a topic

#### **Part I: Initial Discussion**

Begin an initial classroom discussion on important conservation issues and let the students decide which one they think is most important.

#### **Steps**

- Ask students what they think are important conservation issues today
- Facilitate a discussion and let a number of different issues get discussed
- Ask students to point out the pro’s and con’s of each of the issues and how they impact people and the environment
- Let the class choose their favorite issue and write down different points of view on the board

#### **Part II: Group Research**

Let the students use the internet and other media sources to find various points of view on the conservation issue.

#### **Steps**

- Assign students to groups and groups to each of the different points of view
- Let the students conduct background research on their topic: they need to stick to information that supports their point of view

#### **Part II: Group Discussion**

Organize a classroom discussion where students share the point of view they researched on the conservation issue.

#### **Steps**

- Organize the room so that the students are in their groups
- Review the issue and background (if necessary)
- Allow each group to make a statement of their point of view on the issue
- Allow the students to discuss/debate their points of view to each other; facilitate a positive and respectful discussion

## **Art of Experimental Design Teacher Information**

### **6. Science and the Media**

#### **Summary**

Students work in pairs to find a peer-reviewed scientific article and read it. Students analyze their article to make sure it was done correctly and is understandable to the reader. Students discuss their article with the class and state whether or not it met the following conditions: hypothesis clear and testable, methods done with a control and replication, conclusions aligned with results of the experiments. Students also discuss improvements to the article and potential further research.

#### **Objectives**

- To read a peer-reviewed scientific article
- To think critically about a how a scientific article is written

#### **Instructions for Students**

- Work with a partner and find a peer-reviewed scientific article that is of interest to you
- Analyze the article and make sure it met the following conditions:
  - Is the hypothesis clear?
  - Is the hypothesis testable?
  - How has the experimenter controlled the experiment?
  - Were the controls sufficient for eliminating bias?
  - Did the experimenter use enough replicates in order to be sure of his/her findings?
  - Do the conclusions make sense?
  - Did the experimenter suggest improvements or other avenues of further research?
  - Can you think of any improvements or other avenues of further research that could make the results more clear?
  - Was there anything that the researcher should have made clearer in order for others to repeat his/her experiment?
  - Did the researcher leave anything out of his/her paper that would have been useful in interpreting the results?

**Art of Experimental Design  
Teacher Information**

**Worksheet for the Scientific Method**

**Answer the questions and follow these steps of the Scientific Method.**

**Step 1: Ask a question or make an observation**

What are you curious about, or what have you seen that you would like to know more about?

**Step 2: Write a hypothesis**

What do you think is the answer to your question or the reason for your observation? What are some if/then statements that you could write in the form of a hypothesis?

**Step 3: Design an experiment and conduct trials**

What will you do to test your hypothesis? Make a drawing and explain how you will do it.

**Step 4: Accept or reject your hypothesis and state your conclusions**

Can you accept your hypothesis? It's okay if you can't, because we still learn something new. Should you restate your hypothesis or redesign your experiment?

# Art of Experimental Design

## Teacher Information

### Art of Experimental Design Curriculum Links

#### Learning Outcomes

The lesson plans found on this website complement the BC Ministry of Educations

Curriculum IRPs. We've listed the learning outcomes from the following organizers, which are covered by the lessons described.

**AV = Aquarium Visit**

**RM = Research and the Media**

**WH = What is a Hypothesis?**

**EE = Experimental Ethics**

**SP = Scientific Experiment Poster**

**CD = Conservation Discussion**

**SM = Science and the Media**

<b>Grade 8</b>							
<b>LEARNING OUTCOME - Processes of Science</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
demonstrate safe procedures	.				.		.
perform experiments using the scientific method	.		.				
represent and interpret information in graphic form	.		.		.		
demonstrate ethical, responsible, cooperative behaviour	.			.			
<b>LEARNING OUTCOME - Comprehend and Respond</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
identify and discuss the advantages and limitations of a variety of media and explain their effects on people's behaviour	.	.					.
describe and give examples to explain their personal criteria for assessing and responding to what they view, read, or hear	.					.	

<b>Grade 9</b>							
<b>LEARNING OUTCOME - Processes of Science</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
demonstrate safe procedures	.				.		.
perform experiments using the scientific method	.		.				
represent and interpret information in graphic form	.		.		.		
demonstrate ethical, responsible, cooperative behaviour	.			.			
<b>LEARNING OUTCOME - Comprehend and Respond</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
demonstrate an understanding of the main ideas, events, or themes of a variety of novels, stories, poetry, other print material, and electronic media	.	.					
identify and explain connections between what they read, hear, and view and their personal ideas and beliefs	.					.	

# Art of Experimental Design

## Teacher Information

Art of Experimental Design Curriculum Links

Learning Outcomes

The lesson plans found on this website complement the BC Ministry of Educations

Curriculum IRPs. We've listed the learning outcomes from the following organizers, which are covered by the lessons described.

**AV = Aquarium Visit**

**RM = Research and the Media**

**WH = What is a Hypothesis?**

**EE = Experimental Ethics**

**SP = Scientific Experiment Poster**

**CD = Conservation Discussion**

**SM = Science and the Media**

<b>Grade 10</b>							
<b>LEARNING OUTCOME - Processes of Science</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
demonstrate safe procedures	.				.		.
perform experiments using the scientific method	.		.				
represent and interpret information in graphic form	.		.		.		
<b>LEARNING OUTCOME - Statistics and Probability (Probability and Sampling)</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
critique ways in which statistical information and conclusions are presented by the media and other sources	.	.					
<b>LEARNING OUTCOME - Applications of Science</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
identify and consider ethical implications of scientific investigations	.			.			
<b>LEARNING OUTCOME - Self and Society</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
show a willingness to consider and elaborate on others' ideas or viewpoints	.					.	

<b>Grade 11</b>							
<b>LEARNING OUTCOME - Processes of Biology</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
demonstrate safe and correct technique for a variety of laboratory procedures	.		.		.		.
design an experiment using the scientific method	.		.		.		
interpret data from a variety of text and visual sources	.				.		
<b>LEARNING OUTCOME - Comprehend and Respond (Critical Analysis)</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
identify ways in which mass media influence individual perceptions and social behaviours	.	.					
develop and defend a point of view using evidence from work they have read, heard, or viewed						.	
<b>LEARNING OUTCOME - Module 8: Medicine, Health and Technology</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
identify and discuss issues involving ethics related to medicine				.			

# Art of Experimental Design Teacher Information

## Art of Experimental Design Curriculum Links

### Learning Outcomes

The lesson plans found on this website complement the BC Ministry of Education's

Curriculum IRPs. We've listed the learning outcomes from the following organizers, which are covered by the lessons described.

**AV = Aquarium Visit**

**RM = Research and the Media**

**WH = What is a Hypothesis?**

**EE = Experimental Ethics**

**SP = Scientific Experiment Poster**

**CD = Conservation Discussion**

**SM = Science and the Media**

<b>Grade 12</b>							
<b>LEARNING OUTCOME - Processes of Biology</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
demonstrate safe and correct technique for a variety of laboratory procedures	.		.		.		.
design an experiment using the scientific method	.		.		.		
interpret data from a variety of text and visual sources	.				.		
<b>LEARNING OUTCOME - Comprehend and Respond</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
develop criteria for evaluating the accuracy and objectivity of the information found in a variety of print and electronic sources, including mass media	.	.					
demonstrate a willingness to explore diverse perspectives to develop or modify their points of view	.					.	
<b>LEARNING OUTCOME - Culture and Values</b>	<b>AV</b>	<b>RM</b>	<b>WH</b>	<b>EE</b>	<b>SP</b>	<b>CD</b>	<b>SM</b>
evaluate the components of value systems within and among cultures	.			.			