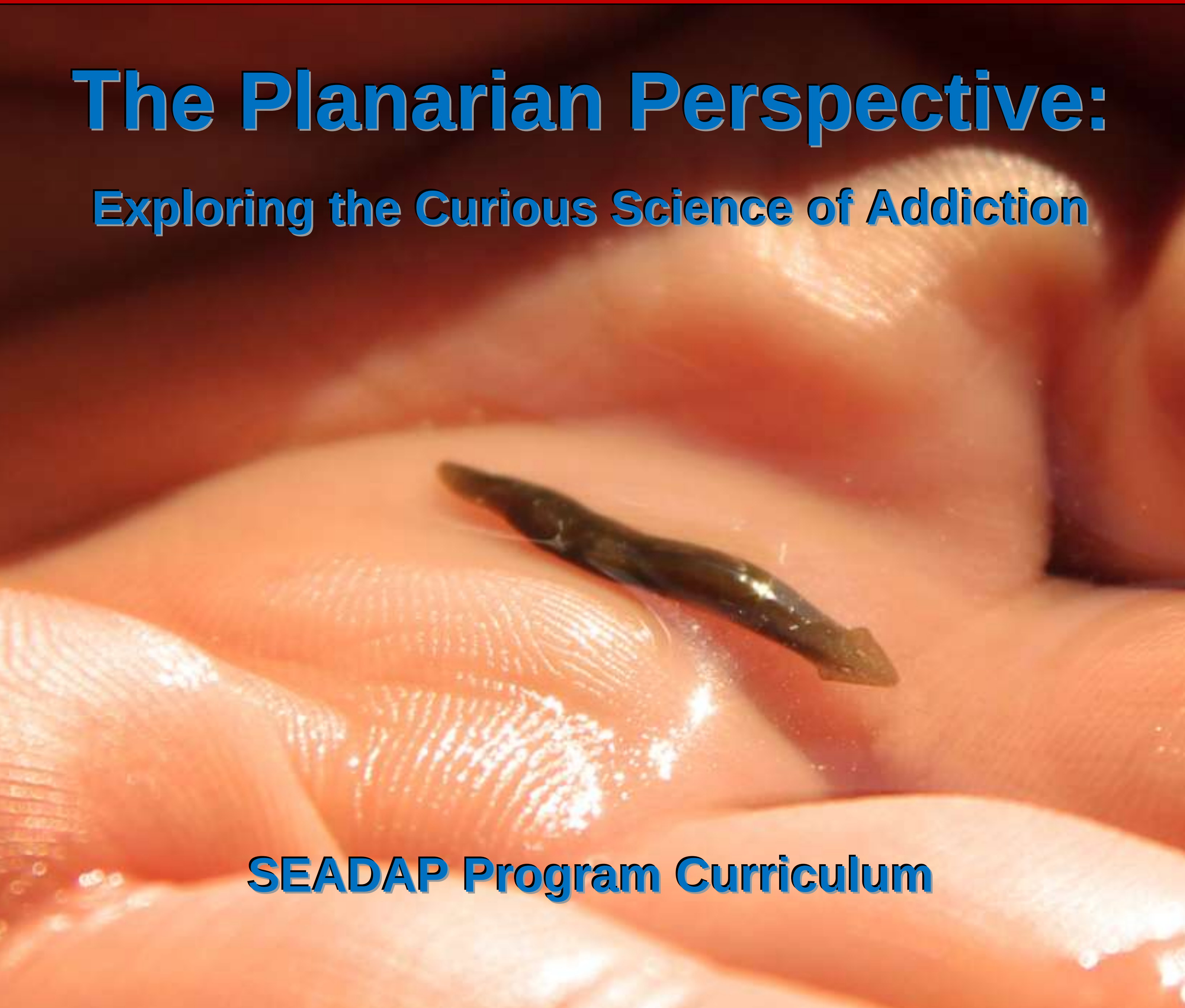
The Planarian Perspective:

Exploring the Curious Science of Addiction



SEADAP Program Curriculum

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NIDA NATIONAL INSTITUTE ON DRUG ABUSE

“Somewhere, something incredible is waiting to be known.”

— Carl Sagan

“The essence of the independent mind lies not in what it thinks, but in how it thinks.”

— Christopher Hitchens

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Background

Approximately 8% of the United States population ages 12 and older are illicit drug users (Substance Abuse and Mental Health Services Administration, 2009). Despite the economic, criminal, and medical consequences associated with drug abuse, most people still do not understand that drug addiction is a brain disease. One strategy to better enhance public awareness about addiction is to develop and implement an educational program to teach the science of drug addiction at the middle and high school levels. Students exposed to such a program could be as knowledgeable about the science and consequences of drug addiction as they are about mathematics, economics, language arts, and history. Current 6-12 grade drug abuse programs are primarily directed toward providing students with information about addiction and abused drugs (e.g., ATOD-TV, If You Drink) or dissuading students from using drugs (e.g., DARE, Life Skills Training). A long-standing gap in drug abuse education that is not addressed by existing programs is the ability for students to conduct and design experiments on live animals.

In vivo effects of addictive substances are typically studied in mammals (humans, mice, rats), but extensive use of mammals in K-12 classrooms is impractical due to economic, practical, legal, and ethical concerns. What is needed to overcome this barrier is a non-mammalian species – one that is scientifically relevant but cheaper and more convenient than mammals. We hypothesize that planarians, an aquatic flatworm, can fulfill this role. In this hands-on, inquiry-based educational program for middle and high school grade levels, students will design and conduct experiments to study the pharmacology of abused drugs (caffeine, nicotine, alcohol, and sucrose) and learn how these pharmacological effects are used to predict and model aspects of human addiction. Planarians are ideal organisms because they have what some consider the earliest 'brain' and possess mammalian-like neurotransmitter systems that are targeted by addictive substances. Dr. Scott Rawls' extensive publication record studying the pharmacological effects of drugs of abuse in planarians indicates that these organisms are ideal for students to study conditions that perpetuate the addictive process, including physical dependence, withdrawal, sensitization, tolerance, and environmental place conditioning. By linking each lesson to National Science Education Standards (NSES) and state standards, incorporating these modules into a broader curriculum is made easier for classroom teachers.

We expect this novel program to achieve the multiple goals of: (a) increasing student knowledge about the science of drug addiction, (b) increasing student awareness about the care and use of animals in basic science research, (c) shifting student attitudes about drug abuse, and (d) enhancing student interest in pursuing biomedical research careers.

Objectives

(1) To apply the scientific method in a meaningful and realistic manner.

(2) To teach students about the science, signs and symptoms, and, ultimately, dangers of drug abuse.

Please refer to individual lessons plans in this booklet for National Science Education Standards (NSES), Next Generation Science Standards (NRC), and Common Core Essential Standards (CCES).

This first edition of the program curriculum also contains North Carolina Essential Standards (NCES) and North Carolina Public Schools Standards (NCPS).

Methods

Inquiry-based learning

Inquiry enables participants to engage in “hands-on-learning” environments. Prevalent reform in science education currently stresses the use of inquiry promoted by National Science Education Standards (NSES). Hands-on learning used as part of an inquiry-based learning approach is recognized as one of the best instructional practices in science education (Colburn, 2000; Banchi and Bell, 2008). Hands-on learning comprises three different dimensions: inquiry dimension, structure dimension, and experimental dimension. In inquiry learning, the student uses activities to make discoveries. The structure dimension refers to the amount of guidance given to the student. If each step is detailed, this is known as a cookbook style lab. These types of activities do not increase a student's problem-solving abilities. The third dimension is the experimental dimension which involves the aspect of proving a discovery, usually through the use of a controlled experiment (Lumpe and Oliver, 1991). An example of how an inquiry-based approach engages students in science at an early age is provided by a study from Purdue University (Riskowski et al., 2009). The study involved 8th graders in a rural Indiana school system. Five classes used a traditional textbook/lecture method to teach students about human impact on water quality. Another five classes were taught about water quality through designing and building actual modules. Students in the latter group were also asked to build a water purification device as a way of learning the concepts. Students who built a hands-on water purification system developed a deeper and better understanding of the concepts of water quality than did students who were simply exposed to the conventional lecture-based approach. The comprehension among students for whom English was not their first language was enhanced by the hands-on learning approach. The study indicates hands-on learning can enhance K-12 science education by boosting comprehension in science, technology and biology and improving critical thinking skills, especially among students from diverse socioeconomic and cultural backgrounds. We predict that the SEADAP program, through a combination of hands-on and inquiry-based strategies, will produce equally positive outcomes on science education as it relates to drug abuse.

Module 1:

The World of Research

(2 Blocks; 50 minutes each)

Lesson 1 *Introduction to Planarians*

Objectives

- To review the scientific method and experimental design.
- To identify and document the basic traits, natural behaviors, and biology of Planarians.
- To understand and use terminology related to Planarians and medical research.

Standards

Science and Engineering Practices [Next Generation, NRC]
- **Developing and Using Models**: Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.
  - Develop and use a model to describe phenomena. (MS-LS1-2)
  - Develop a model to describe unobservable mechanisms. (MS-LS1-7)
- **Planning and Carrying Out Investigations**: Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.
  - Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of an investigation. (MS-LS1-1)

Science as Inquiry (8ASI) [National Science Education Standards, NSES]
- **Abilities necessary to do scientific inquiry** (8ASI1)
  - Identify questions that can be answered through scientific investigations (8ASI1.1)
  - Design and conduct a scientific investigation (8ASI1.2)
  - Use appropriate tools and techniques to gather, analyze, and interpret data (8ASI1.3)
  - Develop descriptions, explanations, predictions, and models using evidence (8ASI1.4)
  - Think critically and logically to make the relationships between evidence and explanations (8ASI1.5)
  - Recognize and analyze alternative explanations and predictions (8ASI1.6)
  - Communicate scientific procedures and explanations (8ASI1.7)

Life Science (8CLS) [NSES]
- **Structure and function in living systems** (8CLS1)
- **Regulation and behavior** (8CLS3)
  - Environmental survival needs (8CLS3.1)
  - Internal regulation for survival (8CLS3.2)
  - Behavioral responses (8CLS3.3)
  - Adaptation (8CLS3.4)

ELA Literacy [Common Core, CCES]

- Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *biology and chemistry*. (RST.11-12.4)
- Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (RST.11-12.7)
- Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (RST.11-12.9)

Vocabulary

Morphology – the branch of biology that deals with the form of living organisms, and with relationships between their structures.

Ventral – A directional term used in the field of biology to describe something located in the front part of the body. In animals, this is usually the surface towards the ground.

Dorsal – A directional term used in the field of biology to describe something located in the back part of the body (in animals with a spinal cord, this is towards the spinal cord).

Posterior – A directional term used in the field of biology to describe something located towards the back of the body, generally away from the head.

Anterior – A directional term used in the field of biology to describe something located towards the front of the body, generally towards from the head.

Eyespots – Simple eyes that can detect light from dark but cannot form images.

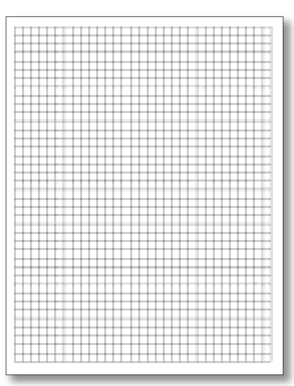
Materials

- 1 Petri Dish (5.5 cm diameter)

- 1 Light Microscope

- 1 Timer

- 1 Sheet of Graph Paper



- 1 Disposable Pipet

- 2-3 Planarians

- 1 Vial of H_2O

- 1 Razor Blade (*See Safety Instructions*)

- Gloves & Safety Goggles


- Lab Manual (+ Writing Utensil)

1. Engagement (5 minutes + 10 minutes)

The introduction to the first lesson, and to the Planarian Perspective program as a whole, will be a review of what the students already know about the scientific method and how it is applied in the real world. Students will be asked to write down and share their answer to the following questions:

"How does the scientific method help you solve problems? Where and how is it used in the real world? Give an example."

Example Answers

a) In the home: Where are my keys?
b) In the community: Who murdered Mr. Green?
c) In science: How does sunlight affect the growth of plants?

The activity should elucidate the misconceptions and limitations of the student's understanding of research in order to generate interest in its application. Once students have been primed in this manner, the planarian perspective program will be introduced: Students will be told that they will simulate medical research by developing a model for drug addiction in planarians. Expectations, the grading rubric (which will be designed by the participating educator), and examples of past student work should be shared at this time.

Please see references (pg. 38) for more resources on teaching the scientific method.

2. Exploration (25 minutes)

Using a series of guiding questions in the lab manual and the above listed materials, students will probe the planarians in various ways and document their findings. They will be prompted to make predictions about the planarians' behavior and test their hypotheses. Specifically, they will:

- Observe the planarians under a light microscope and draw the planarians' morphology.
- Cover half of the Petri dish with a piece of paper to observe that planarians avoid light.
- Record the pattern and average speed of planarian movement using graph paper and a timer.
- Identify that planarians prefer enclosed or protected spaces, such as the sides of the Petri dish.
- Create a current over the planarian with a pipette and observe the planarian's preference for calmer environments (such as still waters).
- Section the planarian into two parts with a razor blade to observe regeneration.
  - We recommend that this be done only by the teacher.
  - Pointed dissection probes, scalpels, razor blades, scissors, and microtome knives must be used with great care, and placed in a safe position when not in use.

Please refer to the student lab manual for more details.

3. Explanation (20 minutes)

In groups of 3-4, students will share their results in order to confirm or deny what they have found. The teacher will go around the classroom to confer with groups. If their understanding is incomplete or their conclusions are incorrect, students should be encouraged to re-attempt that portion of the lab under the supervision of the instructor or capable peers.

As students are looking over their findings, they will fill out a "profile" for the planarians which they will be able to use and refer to in the design of their experiments (during the second module of this program). It will contain basic information about planarians, including a picture, their characteristics, their behaviors, their average movement, etc.

This profile will follow a common format that will be emulated in the next lesson when introducing other animal models. This will allow students to easily compare these various animal models and understand the benefits and disadvantages of each animal type when designing a research study.

Depending on the age group and student interest, this profile can take the form of popular social media websites (i.e. Facebook).

Please refer to the student lab manual for more details.

4. Expansion

This is an optional section for academically motivated classes.

Student groups will be assigned a specific behavior or finding and asked to present their results along with the answer to a series of follow-up questions in the lab manual. These questions, time-permitting, can be answered by the whole class or individual groups. Using an inquiry-based format and connections to student's prior experiences, they will ask students to ponder on the purpose of the various identified properties. For example, students should elucidate that planarians avoid lighted areas as it makes them easier targets to predators. This can be connected to previous biology lessons on evolution by discussing behaviors as evolutionary adaptations.

5. Evaluation

Students will submit one "profile" per group as well as their individual lab manuals. They will be graded according to the rubric previously shared with the classroom.

Alternatively, and time-permitting, students can show what they have learned by presenting the information they have discovered to the rest of the classroom in short 2-3 minute presentations. Various forms of presentation can be used, such as computer projection of drawn images or acting out planarian behaviors using their human counterparts.

Lesson 2 *Introduction to Animal Models*

Objectives

- To explain the benefits and limitations of animal models in medical research.
- To understand the applicability of animal research in humans based on their evolutionary, biological, and behavioral relatedness.

Standards

Life Science (8CLS) [National Science Education Standards, NSES]
- **Unity among organisms**: Millions of species of animals, plants, and microorganisms are alive today. Although different species might look dissimilar, the unity among organisms becomes apparent from an analysis of internal structures, the similarity of their chemical processes, and the evidence of common ancestry. (8CLS5.1)

Science in Personal and Social Perspectives (8FSPSP) [NSES]
- **Science and technology in society**: Science influences society through its knowledge and world view. Scientific knowledge and the procedures used by scientists influence the way many individuals in society think about themselves, others, and the environment. The effect of science on society is neither entirely beneficial nor entirely detrimental. (8FSPSP5.1)

Obtaining, Evaluating, and Communicating Information [Next Generation, NRC]
- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (MS-LS1-8)

ELA Literacy [Common Core, CCES]
- Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *biology and chemistry.* (RST.11-12.4)
- Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (RST.11-12.9)

Vocabulary

Adaptation – a trait that helps an organism survive and reproduce

mya – million years ago

bya – billion years ago

Last Common Ancestor (LCA) or **Concestor** – In a backward chronology, the ancestors of any set of species must eventually meet at a particular geologic moment. The last common ancestor that they all share before separating as two species is the LCA or Concestor.

a) Article about the Last Common Ancestor of cats and dogs (about 55 mya): http://www.gmanetwork.com/news/story/343965/scitech/science/cats-and-dogs-had-a-common-ancestor-and-here-it-is

b) Article about the Last Common Ancestor of humans and chimps (about 7 mya): http://en.wikipedia.org/wiki/Chimpanzee%E2%80%93human_last_common_ancestor

Note: This is also sometimes referred to as the most recent common ancestor (MRCA), although this term is preferentially used to refer to groups within a species.

Materials

- PowerPoint
- Guided Notes (Optional)

1. Engagement (5 minutes)

This section will serve as an introduction to animals used in research, and their importance in understanding and fighting disease. Students will begin by answering the following question, which will serve as a bridge into a discussion about animals as research subjects in medicine:

“Why are rats and mice so often associated with medical research?”

> Answer (from Wikipedia): Mice are the most commonly used vertebrate species, popular because of their availability, size, low cost, ease of handling, and fast reproduction rate. They are widely considered to be the prime model of inherited human disease and share 99% of their genes (and 75% of their genome) with humans. With the advent of genetic engineering technology, genetically modified mice can be created to order rather cheaply.

2. Exploration (15 minutes)

Ask the students: “What type of research could we only do on animals? Why?”

Examples will be provided of important medical breakthroughs that have been made possible through the responsible use of animals in research, both within and outside the discipline of substance abuse research. Proper care and responsible use of animals and the regulations which are in place to ensure such care and use will also be discussed.

Year	Medical Advancement	Animal credited
1796	Smallpox vaccine developed	Cow
1881	Anthrax vaccine developed	Sheep
1885	Rabies vaccine developed	Dog, Rabbit
1902	Life cycle of Malaria discovered	Pigeon
1919	Immunity mechanisms discovered	Rabbit, Horse, Guinea Pig
1921	Insulin discovered	Dog, Fish
1932	Neuron function discovered	Cat, Dog
1933	Tetanus vaccine developed	Horse
1939	Anticoagulants developed	Cat
1954	Polio vaccine developed	Mouse, Monkey
1956	Open-heart surgery & pacemakers developed	Dog
1964	Cholesterol regulation discovered	Rat
1973	Social & behavioral patterns in animals discovered	Fish, Bee, Bird
1982	Leprosy treatment developed	Armadillo
1990	Organ transplant techniques advanced	Dog, Pig, Sheep, Cow
1997	Prions discovered & characterized	Hamster, Mouse
2000	Brain signal transduction discovered	Sea Slug, Mouse, Rat
2002	Cell death mechanism discovered	Worm

Source
"The Proud Achievements of Animal Research", Foundation for Biomedical Research (2003)

3. Explanation (30 minutes)

Using a more conventional direct instructional approach, the teacher will explore three common animal models: Fish, Rats/Mice, and Primates. For each animal model, common key features will be explored, including: genetics (genome, last common ancestor with humans), intelligence, and environmental interactions. Using this information, students will deduce what is the most likely application of these animal models and how well research on them translates to the humans. For each animal model, examples of common research will be shown using videos (e.g., YouTube) and other media.

Students will follow the PowerPoint using the same profiles used the day prior to detail planarians. Guided questions will help them further explore the basic facts provided to understand the use and applications of these various animal models. Key vocabulary words, such as “Last Common Ancestor” will also be defined and used by the students.

Please refer to the PowerPoint for more details.

4. Expansion

This is an optional section for academically motivated classes.

When presented with a fourth and fifth unknown animal model (Birds and Rabbits), students will predict key properties, such as the Last Common Ancestor (LCA) and genetic relatedness, as well as determine the applicability and usefulness of these models with regards to humans.

5. Evaluation

(Optional) For homework, students will be asked to research and submit one paragraph on a recent breakthrough in medical science of their choice that was due to animal models.

Students can choose any reputable source for their work. Alternatively, they can use the following student-friendly website: http://www.reddit.com/r/animalresearch/ as a starting point for finding current trends in animal research. Students should be encouraged to properly verify the legitimacy of their sources (e.g., websites ending in .edu, scientific journals, etc).

Lesson 3 (Optional) *The Ethics of Research*

Objectives

- To evaluate and prepare various arguments for and against the use of animal models in medical research.

Standards

Structures and Functions of Living Organisms [NCES / NCPS]

- Understand how biotechnology is used to affect living organisms. (8.L.2)
- Summarize aspects of biotechnology including: Ethical issues. (8.L.2.1)

Science and Technology (8EST) [National Science Education Standards, NSES]

- **Understandings about science and technology**: Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot. (8EST2.6)

Obtaining, Evaluating, and Communicating Information [Next Generation, NRC]

- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (MS-LS1-8)

ELA Literacy [Common Core, CCES]

- Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved. (RST.11-12.6)
- Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (RST.11-12.7)

Vocabulary

Animal rights - Belief that animals should not be exploited (i.e. not used for food, clothing, entertainment, medical research, product testing).

Animal welfare - Belief that animals should be treated humanely (i.e. properly cared for, have adequate housing, nutrition, health care, and humanely).

Ecoterrorism - Terrorism or crimes committed under the disguise of saving nature.

Humanize - To believe that animals have the same rights as humans and to treat them as humans.

Specieism - Belief that any use of animals by humans reflects a bias or that humans are superior to animals.

Unethical - Belief that something is going against one's moral principles or values.

Vivisection - Research consisting of surgical operations and experiments to study the structure and functions of organs.

Materials

- PowerPoint
- Guided Questions

1. Engagement (5 minutes)

A basic philosophical dilemma related to animal research will prompt students to identify their position on the issue. By vote of hand, students will be asked to determine if they believe the statement below to be true or false.

“We must make animals sick, give them drugs, and at times kill them in order to improve the human condition.”

2. Exploration (10 minutes)

Following a short introduction to the modern proponents (e.g., Pharmaceutical Companies) and opponents (e.g., PETA) of animal research, students will be given some fact and figures about animal research in the USA. Have students try to make some predictions about the scope of animal research before sharing these numbers with them. These facts and figures are meant to provide material that the students can refer back to when crafting their arguments in the ensuing debate.

Example

- In 2012 US government statistics put the number of laboratory animals used in research at 953,077, a 16% drop from 2010. It is important to note that these statistics do not include rats, mice, birds and fish, as these animals are not covered by the Animal Welfare Act. In actuality, the number of animals in research is closer to 26 million (Source: www.thehastingscenter.org).

Please refer to the PowerPoint for a complete list of these statistics.

3. Explanation (30 minutes)

After identifying their personal position (for or against) animal research, students will be organized according to the side they want to argue. However, as a twist, they will be asked to argue the opposite position. This helps students to be more thoughtful about others' points of view and to be more thorough about defending their own.

Student roles should be assigned to facilitate the debate. A rotating leader will present the team's argument each round and their rebuttals. Additionally, fact sheets can be made available to allow students to supplement their arguments with additional evidence that was not present in the introduction.

The debate format is as follows:

a) A series of statements, facts, and pictures (http://animal-testing.procon.org/) will be presented on board using PowerPoint.
b) Each side will have 5 minutes to craft their initial arguments. After a coin flip to determine the starting team, each side will have 2 minutes to present their initial arguments.
c) Each side will then have 2 minutes to prepare a 1 minute rebuttal which will proceed according to the order determined by the coin flip.
d) A second round of rebuttal can occur at the teacher's discretion.

4. Expansion (5 minutes)

In a short reflective summary, students will be asked to identify the most thought-provoking argument of the day and explain how it has, if at all, changed or reinforced their personal opinion of animal research.

5. Evaluation

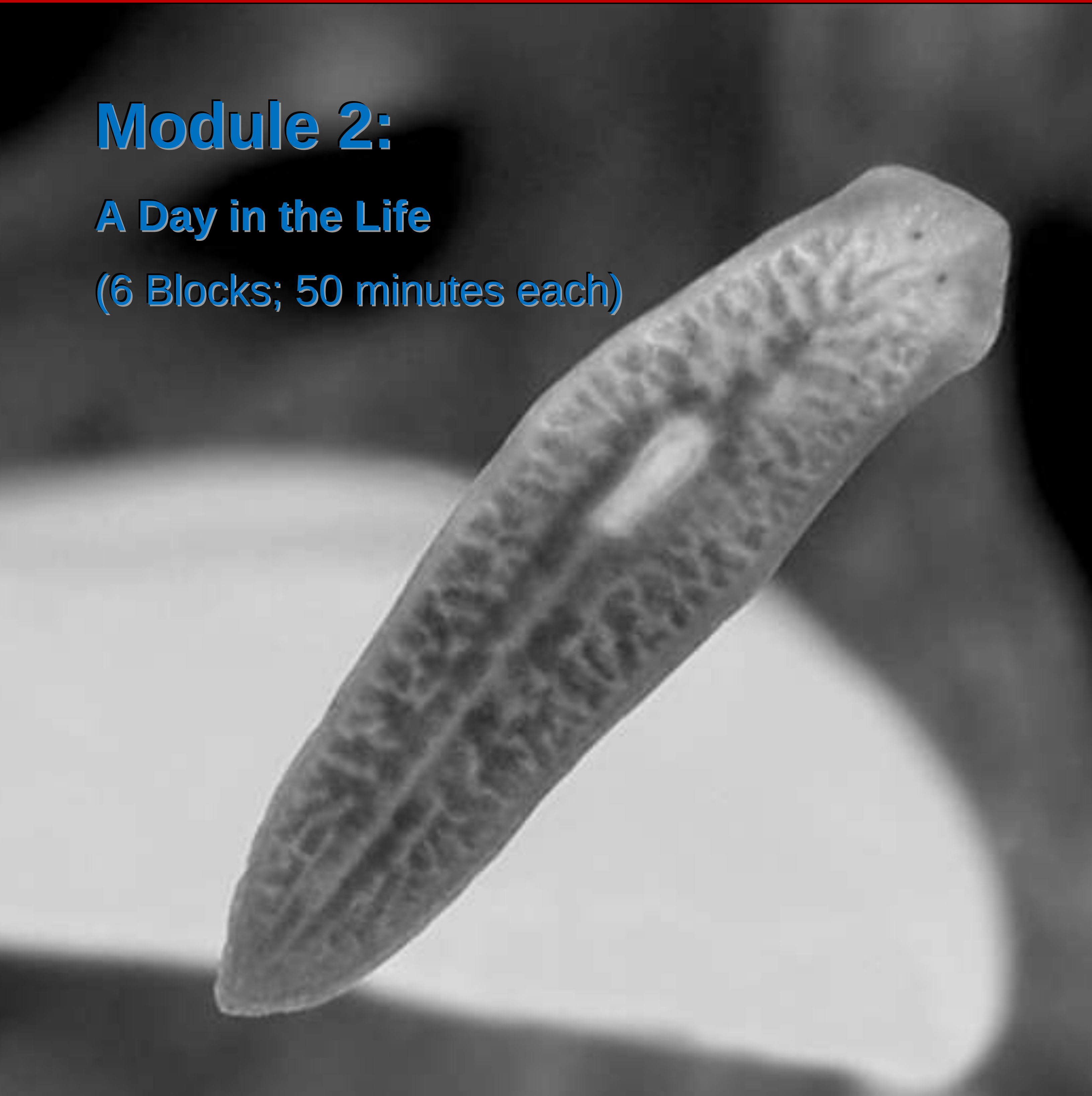
Student participation in the debate will be evaluated using a teacher-made rubric which can be filled out while observing and moderating.

(Optional) For homework, students will be asked to identify one unanswered question from the debate and to research it online.

Module 2:

A Day in the Life

(6 Blocks; 50 minutes each)



Laboratory *Medical Research Simulation*

Objectives

- To explain the various roles in academic research and its system of checks and balances.
- To plan and execute addiction research on planarians.

Standards

Science and Engineering Practices [Next Generation, NRC]

- **Developing and Using Models**: Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.
    - Develop and use a model to describe phenomena. (MS-LS1-2)
    - Develop a model to describe unobservable mechanisms. (MS-LS1-7)
- **Planning and Carrying Out Investigations**: Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.
    - Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of an investigation. (MS-LS1-1)

Science as Inquiry (8ASI) [National Science Education Standards, NSES]

- **Abilities necessary to do scientific inquiry** (8ASI1)
    - Identify questions that can be answered through scientific investigations (8ASI1.1)
    - Design and conduct a scientific investigation (8ASI1.2)
    - Use appropriate tools and techniques to gather, analyze, and interpret data (8ASI1.3)
    - Develop descriptions, explanations, predictions, and models using evidence (8ASI1.4)
    - Think critically and logically to make the relationships between evidence and explanations (8ASI1.5)
    - Recognize and analyze alternative explanations and predictions (8ASI1.6)
    - Communicate scientific procedures and explanations (8ASI1.7)

Life Science (8CLS) [NSES]

- **Structure and function in living systems** (8CLS1)
- **Regulation and behavior** (8CLS3)
    - Environmental survival needs (8CLS3.1)
    - Internal regulation for survival (8CLS3.2)
    - Behavioral responses (8CLS3.3)
    - Adaptation (8CLS3.4)

Obtaining, Evaluating, and Communicating Information [Next Generation , NRC]

- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (MS-LS1-8)

Science in Personal and Social Perspectives (8FSPSP) [NSES]

- **Science and technology in society**: Science influences society through its knowledge and world view. Scientific knowledge and the procedures used by scientists influence the way many individuals in society think about themselves, others, and the environment. The effect of science on society is neither entirely beneficial nor entirely detrimental. (8FSPSP5.1)

Structures and Functions of Living Organisms [NCES, NCPS]

- Understand how biotechnology is used to affect living organisms. (8.L.2)
- Summarize aspects of biotechnology including: ethical issues, careers, etc. (8.L.2.1)

Science and Technology (8EST**)** [NSES]

- **Understandings about science and technology:** Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot. (8EST2.6)

ELA Literacy [Common Core, CCES]

- Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. (RST.11-12.3)
- Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved. (RST.11-12.6)
- Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (RST.11-12.7)
- Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (RST.11-12.9)

Vocabulary

Classical Conditioning (or **Pavlovian Conditioning**) **–** A learning process that occurs when two stimuli are repeatedly paired; a response that is at first elicited by the second stimulus is eventually elicited by the first stimulus alone. For example, ringing a bell every time food is served to a dog can eventually cause them to salivate when only the bell is rung.

Nerve – A bundle of fibers composed of neurons through which the brain and body communicate.

Nerve cords – The long nerves running from the ganglia in the head of a planarian through its body. Nerves connect the nerve cord like rungs on a ladder.

Neurotransmitter – Chemicals that communicate information across the synapse to communicate from on neuron to another.

Synapse – Chemical or electrical junctions that allow electrical signals to pass from neurons to other cells. A synapse includes a synaptic terminal, synaptic gap, and a dendrite.

Receptor – An area of the neuron that is specialized for receiving neurotransmitter.

Stimulant – Chemicals that increase mental or physical function by increasing alertness and decreasing sleepiness.

Depressant – Chemicals that decrease mental or physical function by decreasing alertness and increasing sleepiness.

Peer Review – Evaluation of work by one or more people of similar competence to the producers of the work. In science, this is done to ensure that results are reproducible and valid.

Materials

- 4 Petri Dish (5.5 cm diameter)

- 6-10 Planarians

- 2 Disposable Pipet

- 1 Vial of H_2O

- Gloves & Safety Goggles


- Lab Manual (+ Writing Utensil)

Exact materials needed will depend on the student's experimental design, but can also include:

- 1 Vial of Solution (0.10 M Nicotine, 0.10 M Sucrose, or 0.10 M Ethanol)
- Timer
- Sheet of Graph Paper
- Light Microscope
- Razor Blade
- Filter Paper

1. Engagement

Day 1:
Because of its fundamental role in creating models for drug addiction in planarians, classical conditioning will be introduced to the students as a fun opening activity. A variety of demonstrations described online can be used for this purpose, including the following:

(1) http://www.livestrong.com/article/349928-classical-conditioning-classroom-exercises/
(2) http://www.psych.washington.edu/Foundations/Quarters/King/Learning/BehavioristHatOnline/ClassicalDemoInstruct.html

Alternatively this can be pre-work for the students done at home, with a review activity in class.

Following this, a video introduction by Dr. Rawls will provide the students with an overview of the "current" trends in medical research on planarians and drug abuse. In order for the students to come up with their own ideas, the video will present a review of outdated literature that was available right before planarians began to be used as models for drug addiction. Planarian behaviors of interest, further concepts in conditioning, and other observations will be detailed in a manner that allows the students to make their own connections and conclusions, "connect the dots."

An overview of the structure for the following days will be presented to the students, as well as a list of the various roles in research:
(1) Medical Researchers
(2) NIH Funding Board
(3) Ethics Board
(4) Peer Reviewers

A specific overview of the "Medical Researcher" will be presented by the instructor using PowerPoint and another video by Dr. Rawls. It will detail their work, education, salary, and lifestyle. Their relationship to other organizations and individuals will be shown graphically.

2. Exploration

Please refer to the student lab manual for the guiding template.

Students will then be asked to identify a topic in planarian research they are interested in exploring (i.e., Light seeking behavior after alcohol exposure). Groups of students will be assigned by the instructor. Once in groups, the students will create, using a guiding template, a research proposal including their research methods and proposed procedures. Students will be encouraged to role-play and put themselves in the shoes of a research using prompts:

"You are an academic researcher at a medical school. As an expert on planarians, you are designing an experiment to demonstrate the addictive qualities of Nicotine…"

Day 2:
An abbreviated version of the classic plane crash survivor game below can be used as an introduction to the concept of resource allocation and, optionally, as a team-building exercise: http://humanservices.ucdavis.edu/resource/uploadfiles/Survival%20Crash%20Scenario.pdf

Once students understand the basic principles of resource allocation, they will be given a specific overview of the “NIH Funding Board” and the “Ethics Board” using PowerPoint and videos recorded by an NIH researcher (To be determined) and a Temple Ethics Board member (Dr. Nora Jones). It details the organizations, their purpose, the process of funding application, and a graphic representation of their relationship to other organizations and individuals.

The instructor will have **previously** compiled the student’s research proposals, creating a brief synopsis of each proposal and its methods. This should be done after the end of the first day’s activities using any preferred media. Student’s names and identifying information should be removed in order to avoid the following activity becoming a “popularity contest.” If there is more than one class, consider switching up the classrooms. Consider asking students to type their proposals to make it easier to prepare the compilation and for ease of reading.

Students will model the National Institute of Health (NIH) as a classroom and each student will be given a specific amount of funding to distribute. Each “research bill” (representing the fictional sum of $50,000; consider that the average grant funded by the NIH in 2013 was $488,945) will represent funding for one project. However, students will be given a lesser number of bills than the total number of projects so that funding decisions will have to be made (For example, in a class of 30 with 10 projects, each student could be given 5 bills). After listening to the grant proposals, the classroom will be asked, in a respectful manner, to discuss each project and its pros and cons. They will then be asked to allocate their funds to the various projects. No restrictions should be made to self-funding their own projects as this may prevent embarrassment should certain projects be underwhelming. However, funding other people’s projects should be encouraged. Students can only fund each project with one bill.

Optional: Additionally, a miniature “ethical review board” can be conducted to ensure that the research is sound and not unnecessarily cruel to animals. Since none of the student’s projects should be egregiously unethical, a review of fake proposals that present various ethical dilemmas should be prepared ahead of time (this supplemental item is in development).

Day 2.5 – 3:
Students will modify their research plan based on the feedback of their peers and with the guidance of their instructor. Students will then gather materials (from the list above), and execute their research plans to get data. The teacher can allow materials beyond the list above to be obtained by special request.

Time-permitting, the teacher can make further use of the “research bills” and ask students to “purchase” materials for their project like actual researchers from a “store.” This may be time-consuming, and is therefore an optional activity. However, it does mimic reality better and adds an additional and fun layer to this simulation. In case the teacher decides to implement this, students should be allowed to earn extra money from their teacher if feedback from other students is well addressed in their proposal.

3. Explanation

Day 4:
Students will produce a “research paper” which details their objective, their methods, and their preliminary results. **Analysis of results will be reserved for later**. This should be an improved and modified version of their previous proposal. For this reason, we encourage students and teachers to use computers.

Following a brief introduction to the concept of peer review and its importance in the scientific world, students will be told to prepare their research papers with instructions clear enough for someone else to follow.

Using examples, the teacher should instruct students on how to properly write instructions:
http://www.wikihow.com/Write-Clear-Instructions
(e.g., How to find a tree; How to make a sandwich)

4. Expansion

Day 5:
Switching off with other groups, students will “peer review” each other’s research and possibly provide each other with additional data for later. The **results should not be shared** between groups before the peer review process in order to ensure there is no bias on the part of students. Students will provide each other with materials by cleaning and reusing appropriate items and getting fresh planarians, water, and depleted items from the teacher.

Students should be instructed to the follow the instructions as literally as possible. This can create amusing situations and invalid results (which should not be used in data analysis), but will serve as an excellent teaching opportunity.

Day 6:
Students will prepare a final research paper and present their results using mathematical analytic techniques. They can, and should, use the data produced by the "peer review" unless it is invalidated because of faulty instructions. Process skills that have been previously used in the classroom, such as creating graphs, should be employed. Students should confirm or deny their hypothesis and state the results that support their position.

Optional: In an advanced classroom, the concepts of p-values as a scientific benchmark for valid research can be introduced, calculated, and analyzed. This would be a good opportunity to collaborate with the math teacher. Below are some suggested websites for exploring the concept of p-values:

(1) http://en.wikipedia.org/wiki/P-value
(2) https://www.youtube.com/watch?v=eyknGvncKLw
(3) http://www.gla.ac.uk/sums/users/jdbmcdonald/PrePost_TTest/pandt1.html
(4) http://www.informationweek.com/big-data/big-data-analytics/should-high-schools-teach-big-data/d/d-id/1106867

Optional: As in the real world, student work should be "published" in a scientific journal. In order to appeal to creative students, a side project can involve the creation of a magazine cover based on one of the famous scientific journals like *Nature*. This can also serve as an excellent opportunity to introduce students to scientific publications.

5. Evaluation

Students will be graded on a teacher-created rubric based on the final research paper they produce as a group. It should be emphasized that the validity or accuracy of their data will not be a large portion (if any) of their grade. Rather, their research methods, ability to write and follow instructions, analysis of results, and identification of sources of errors are emphasized.

Module 3:

Coming to Conclusions

(2 Blocks; 50 minutes each)

Lessons 4 & 5 *Interpreting Results*

Objectives

- To examine research articles and to explain the implications of its results to a peer.

Standards

<u>Science and Engineering Practices</u> [Next Generation, NRC]

- **Developing and Using Models**: Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.
  - Develop and use a model to describe phenomena. (MS-LS1-2)
  - Develop a model to describe unobservable mechanisms. (MS-LS1-7)
- **Planning and carrying out investigations** in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions.
  - Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of an investigation. (MS-LS1-1)

<u>Science as Inquiry (8ASI)</u> [National Science Education Standards, NSES]

- **Abilities necessary to do scientific inquiry** (8ASI1)
  - Identify questions that can be answered through scientific investigations (8ASI1.1)
  - Design and conduct a scientific investigation (8ASI1.2)
  - Use appropriate tools and techniques to gather, analyze, and interpret data (8ASI1.3)
  - Develop descriptions, explanations, predictions, and models using evidence (8ASI1.4)
  - Think critically and logically to make the relationships between evidence and explanations (8ASI1.5)
  - Recognize and analyze alternative explanations and predictions (8ASI1.6)
  - Communicate scientific procedures and explanations (8ASI1.7)

<u>Life Science (8CLS)</u> [NSES]

- **Structure and function in living systems** (8CLS1)
- **Regulation and behavior** (8CLS3)
  - Environmental survival needs (8CLS3.1)
  - Internal regulation for survival (8CLS3.2)
  - Behavioral responses (8CLS3.3)
  - Adaptation (8CLS3.4)

<u>Obtaining, Evaluating, and Communicating Information</u> [Next Generation, NRC]

- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (MS-LS1-8)

Structures and Functions of Living Organisms [NCES / NCPS]
- Understand the hazards caused by agents of diseases that affect living organisms. (8.L.1)

ELA Literacy [Common Core, CCES]
- Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (RST.11-12.1)
- Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (RST.11-12.2)
- Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (RST.11-12.8)
- By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently. (RST.11-12.10)

Vocabulary

Sample Size – Number of units which are to be included in the sample that is measured.

Reproducibility – Degree of agreement between measurements conducted on similar specimens in different locations by different people.

Applicability – Usefulness of something for a particular task.

Association / Correlation – When researchers find a correlation, which can also be called an association, what they are saying is that they found a relationship between two, or more, variables**.** For instance, in the case of marijuana, the researchers found an association between using marijuana as a teen, and having more troublesome relationships in mid to late twenties. This does not imply one must cause the other, it just says that, somehow, they are related to one another.

Causation – When an article says that causation was found, this means that the researchers found that changes in one variable they measured directly caused changes in the other. An example would be research showing that jumping off a cliff directly causes great physical damage.

Materials

- PowerPoint
- Selection of Research Articles on Drug Abuse

1. Engagement (10 minutes)

Day 1:
Students should have available their prior research results.
Note: These lessons have to be done in order.

"We have results! Off the top of your head, as if you had to explain them to your 5 year old sibling, what do they mean … for Planarians? … for Humans?"

In pairs that did not work together previously on a research project, student will be asked to briefly state (in no more than 4-5 sentences) the implications of their research on planarians and to extrapolate to humans. They will then write down these statements as a diagnostic of their current understanding of how research can be applied outside of the laboratory. It should be kept for future revision.

2. Exploration (25 minutes)

In a more traditional lecture format, students will be introduced to the structure and format of scientific papers (For example, they usually contain an abstract or summary, a list of methods, a data section, and a conclusion). They will also be asked to predict why sample sizes, reproducibility, applicability, are important and taught the difference between association and causation.

See above for a list of vocabulary words.

Various examples of mistakes in these articles (in their methodology, structure, or conclusions) will be presented and student participation should be elicited in their identification.

Following this, specific sentences pulled from various research articles will be shown side by side with a layman's sentence describing it. Students will be asked to identify correct and incorrect interpretations.

Example

> *Research Article*: "Cocaine dependent individuals discount future rewards more than future losses for both cocaine and monetary outcomes."
>
> *Translation*: "People on cocaine are much more willing to accept smaller amounts cocaine or money immediately (despite being offered larger amounts later), and they are less willing to lose smaller amounts of cocaine or money in the short term (despite being told this means they will lose larger amount later)."

Source: http://www.ncbi.nlm.nih.gov/pubmed/25260200

3. Explanation (15 minutes)

Students will then critically examine their own research and the conclusions they made from them in the beginning of the classroom. Referring back to their data and hypothesis, they will draft an analysis and conclusions that are specific to their research.

They will then swap their papers and judge each other's research using similar criteria by which we judge any research: For example, were its results reproducible? Was the sample size large enough? How applicable were its conclusions to human models and was this reflected in their conclusion? Why can't you do that?

4. Expansion (30 minutes)

Day 2:
On the second day of result analysis, the students will apply these analytic skills in order to review a selection of real research articles on drugs. The classroom instructor will first demonstrate how to deconstruct and analyze a research article before dividing students into groups. Each group of students can analyze a specific category of drugs (ex. opiates) or a specific feature of drugs (e.g., addiction potential). The selection of articles can be topically based on regional drugs of abuse (e.g., Methamphetamines).

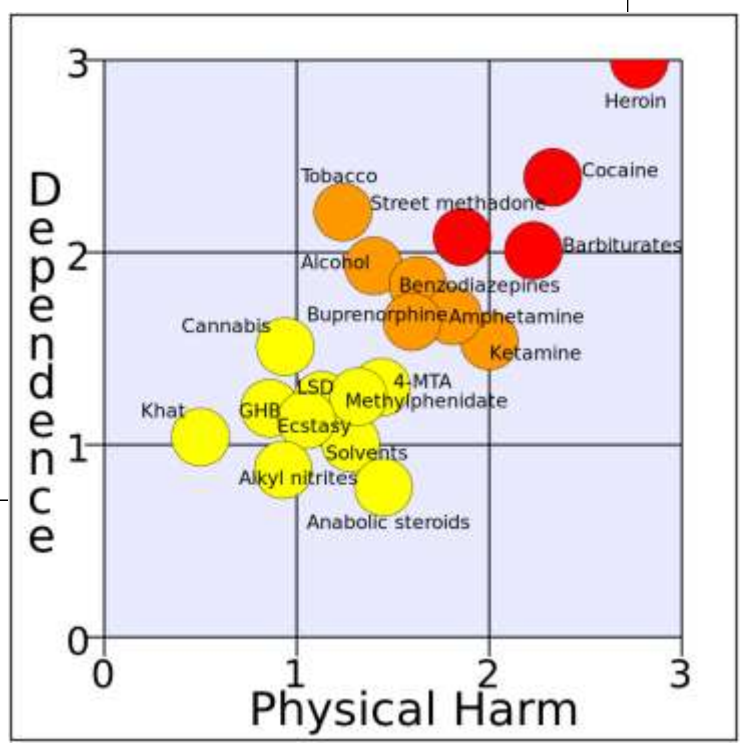
Optional: Alternatively, depending on classroom needs, students can analyze data about drugs presented in a question format similar to the ACT / SAT or state standardized tests. These tests focus on data and table analysis. Time should be allotted to allow open discussion as questions by students arise naturally.

5. Evaluation (20 minutes)

The students will present their research to the classroom and will be graded on a rubric based on the quality of their presentation and its conclusions. Students will be asked to classify various drugs on a chart (as is shown here) contrasting dependence and physical harm.

Source: Wikipedia [1]

Please note: Graphical data presented here is not based on facts or medical research but on questionnaire results of experts (such as psychologists and policemen).



[1] http://upload.wikimedia.org/wikipedia/commons/9/9c/Rational_scale_to_assess_the_harm_of_drugs_%28mean_physical_harm_and_mean_dependence%29.svg

Addendum

Student Research Opportunities

Dr. Scott Rawls, one of the co-investigators leading the development of this program, is an active researcher at the Temple University School of Medicine. His laboratory uses vertebrate (rats, mice) and invertebrate (planarians) models to investigate the pharmacology of drugs of abuse such as cocaine, amphetamines, and opioids.

High school and college students interested in a summer research fellowship, in particular those identified by their teachers as exhibiting an avid interest in this subject matter, are invited to contact Dr. Rawls directly at srawls@temple.edu.

You can read more about Dr. Rawls' research interests by going to the following website: http://www.temple.edu/medicine/faculty/r/rawls.asp

Sending us Feedback

We welcome any suggestions, questions, or materials (such as modifications to the curriculum, additional lesson plans, rubrics, exceptional student work, etc.) that you would generously like to offer us. Your help is invaluable in the continued improvement of this program!

Please contact Dr. Rhea Miles at milesr@ecu.edu.

References

1. Substance Abuse and Mental Health Services Administration. (2010). Results from the 2009 National Survey on Drug Use and Health: Volume I. Summary of National Findings (Office of Applied Studies, NSDUH Series H-38A, HHS Publication No. SMA 10-4586 Findings). Rockville, MD

2. National Committee on Science Education Standards and Assessment. (2005) *National Science Education Standards.* Retrieved from http://pals.sri.com/

3. National Research Council. (2014). Next *Generation Science Standards.* Retrieved from http://www.nextgenscience.org/next-generation-science-standards

4. Public Schools of North Carolina, State Board of Education/Department of Public Instruction. (2010). North *Carolina Common Core and Essential Standards.* Retrieved from http://www.ncpublicschools.org/docs/acre/standards/new-standards/science/6-8.pdf

Additional Resources

<u>Scientific Method</u>

A. Covitt, B. A., Harris, C. B., & Anderson, C. W. (2013). Evaluating Scientific Arguments with Slow Thinking. *Science Scope*, 44-52.

   Abstract: Information is provided on several educational activity programs designed to promote scientific understanding in students using a process referred to as slow thinking that modifies instant perceptions and conclusions.

B. Davis, S. L. (2012). Applying the Scientific Method & Phylogenectics to Understand the Transition from Kingdoms to Domains: Does One Plus One Equal Five, Six, or Three. *American Biology Teacher, 74*(5), 332-334.

   Abstract: The progression of the taxonomic organization of life from Linnaeus's original two kingdoms to the traditional five-kingdom system to today's widely accepted three-domain system is explored in a group-learning activity. Working with a set of organisms, students organize them into each system. Discussion after each step focuses on viewing classification schemes as hypotheses about the relatedness of organisms and how hypotheses are altered with accumulation of new data. Finally, the connection between phylogenetic trees and the hierarchal system of biological classification is emphasized by using tree-thinking to analyze the universal phylogenetic tree as the basis of the three-domain system.

C. Hope, G., Schachter, R., & Wasik, B. (2013). Using the Scientific Method to Guide Learning: An Integrated Approach to Early Childhood Curriculum. *Early Childhood Education*, 315 - 323.

   Abstract: Researchers and practitioners have become increasingly interested in how early childhood programs prepare young children for science. Due to a number of factors, including educators' low self-efficacy for teaching science and lack of educational resources, many early childhood classrooms do not offer high-quality science experiences for young children. However, high-quality science education has the potential to lay an important foundation for children's knowledge and interest in science as well as reinforcing and integrating critical language, literacy, and math readiness skills. This paper examines the current research on science in preschool classrooms and provides suggestions on how to teach science that supports children's development across domains. Using the scientific method to explore science with young children provides a systematic model for engaging children in observation, questioning, predicting, experimenting, summarizing, and sharing results. These processes encourage children's use of language, literacy, and mathematics skills in authentic ways. Suggestions are provided for teachers to use the scientific method as their guide for generating scientific discovery in their classroom.

D. Orr, T., & Flowers, J. (2014). an experimental approach to...everything! *Technology & Engineering Teacher*, 8-12.

Abstract: The article offers suggestions on carrying out various experiments including educational experimentation, teacher-directed experiments and inquiry approach. Recommendations include determining the problem, constructing hypothesis, analyzing data and drawing conclusions. Also advised is the integration of experimentation into technology education.

E. Riegelman, R. K., & Hovland, K. (2012). Scientific Thinking and Integrative Reasoning Skills (STIRS): Essential Outcomes for Medical Education and for Liberal Education. *Peer Review, 14*(4), 10-13.

Abstract: The article focuses on the Scientific Foundations for Future Physicians report that deals with the medical education and practice of education and recommends that there is a necessity of acquiring knowledge and skills in critical analysis, statistical inference and experimental design. It discusses Scientific Inquiry and Reasoning Skills (SIRS) framework which comprises of several skills including knowledge of scientific concepts and principles, scientific reasoning and evidence-based problem solving and reasoning about the design and execution of research.