ENHANCING SCIENTIFIC LITERACY: A RESOURCE FOR TEACHERS  Written by:
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The standard science curriculum is meant to familiarize students with basic concepts in biology, chemistry, and physics. We do not dispute the necessity of this – indeed, a strong grasp of the fundamentals will facilitate the understanding of intermediate and advanced topics later on. Unfortunately, the evaluative approaches in these courses often misinform students of what it means to be a scientist. Students, especially those interested in biology, may be tempted to correlate scientific potential with the ability to retain and recall information for an exam. But that’s not science. As a professor once said at a first-year biology seminar, “We do a good job of teaching you the ‘what’. But we gloss over the ‘how’ and the ‘why’.”

This scientific literacy package aims to enhance students’ fluency of primary research articles, helping them develop essential skills for future scientific careers. Over the course of the semester, your students will (1) gain a deeper understanding of the scientific process, (2) learn to interpret scientific graphs and figures, and (3) consider the implications of various scientific advancements. We have provided a structured learning plan to achieve these goals.

LEARNING PLAN

This scientific literacy package should take nine weeks to complete, assuming one or two lessons per week. As the teacher, you should select primary research articles for students to read based on their ability level and interests. At the beginning of the nine weeks, instructors should notify students of mandatory course projects that are due at the end of the semester or term. Students have the option of completing either a scientific review (individual assignment) or a multimedia project proposal (assignment for 1-4 students). For the remainder of the nine weeks, students will be reading and discussing scientific papers.

Note: The Foundation for Student Science and Technology has scientist and student mentors available to assist students with understanding primary research articles. These mentors would be able to communicate with students through an online medium. To be put in contact with these mentors, please email: brandon.tang@fsst.ca

WEEKS 1-3: COMPREHENSION

This initial phase is directed at having students grasp the fundamentals of the scientific process. During this time, students should focus on identifying various sections of research articles and analyzing the motivations for the research being conducted. Students should be able to understand and communicate main ideas of a paper, including the question/hypotheses, the main experiments, and the results/conclusions. Less focus should be placed on understanding specific methods or data figures.

Sample questions to consider:
• What is the research question?
• Why do the authors care about this question? What is the motivation for this work?
• What sort of experiments were done to address the question (don’t worry about the details)?
• What were the results or conclusions?
• Show us where you can find the ______ (background information / hypothesis / methods / data figures / results / conclusion) in this paper.

Instructors should focus on having the students understand the paper.

WEEKS 4-6: INTERPRETING TABLES AND FIGURES

In addition to what they were doing in weeks 1-3, students should begin to examine the major tables and figures within papers. They should practice drawing conclusions based on the data presented.
and through this process, students will mimic the scientific reasoning that the authors employed. Students should also be encouraged to speculate how the data would look if alternative hypotheses (those contrary to what the data currently support) were true. Although there may be many results in each article, those which are the easiest to interpret and most significant should be focused on.

Sample questions to consider (in addition to those from weeks 1-3):

- (For scatter plots or line graphs). What variables are described by the x and y axes? What is the trend shown on the graph? What does this _____ (line/ marker) indicate? How did the authors interpret this graph?
- (For bar graphs). What is the bar graph comparing? How did the authors interpret this graph?
- (For microscope pictures). What is this a picture of? What does this _____ (color/line/ dot/arrow) represent? How did the authors interpret this picture?
- Let’s pretend that the authors were wrong about their hypothesis. If _______ were true instead, what would this figure look like?
- Remember that it is still important to go through the general comprehension questions from weeks 1-3 before attempting week 4-6 questions:
  - What is the research question?
  - Why do the authors care about this question? What is the motivation for this work?
  - What sort of experiments were done to address the question (don’t worry about the details)?
  - What were the results or conclusions?
  - Show us where you can find the _____ (background information / hypothesis / methods / data figures / results / conclusion) in this paper.

WEEKS 7-9: LOOKING BEYOND

The first six weeks of the scientific literacy course focuses on identifying main sections of scientific papers and understanding the interpretation of data figures. In these last three weeks, students should use these newfound skills to (1) ask probing questions about the scientific articles they read and (2) consider the relevancy of the articles to other science courses, the field of science in general, and/or our daily lives.

Class Structure:

1. Summarize the paper, identifying main points such as the research question, hypothesis, experimental approach, results and conclusions. Use the sample questions from weeks 1-3.
2. Discuss the implications of the conclusions on the overall field of science. Does this paper relate to concepts from other science courses that you have taken? Why is this paper significant for other scientists working in the field?
3. (Challenging) Question the authors’ experimental approach and conclusions. Could anything have been done differently? If you were performing these experiments, what would you improve? Are there any follow-up questions that you may be interested in investigating?

Instructors are encouraged also to return to previous papers that were interesting to students and apply this discussion. This may be especially helpful for students who had difficulty understanding the papers the first time around.

SCIENTIFIC REVIEW ASSIGNMENT GUIDELINES

[FINAL PROJECT]

Overview

To demonstrate their skills in scientific reading and writing, students can write a report based on 5-6 research articles in a field of their choice. The objectives of this assessment are to (1) help students develop scientific literacy skills, (2) immerse students in their topic of interest, and (3) select the most proficient and motivated students for lab-based (or field-based) research. This independent assignment is one of the two options for the final project.

For teachers:

As most of the students will have had limited exposure to scientific reading and writing, your guidance and support will be imperative to
their success. It is recommended that you introduce the assignment at least a month before the first draft is due and use classroom discussions to acquaint students with scientific literature. You may also set aside one classroom period to discuss scientific writing and citations.

At least a month before the assignment is due, students should select 5-6 primary research articles on a topic of their choice. The topic should be broad enough so that minimal specialized knowledge is required to understand the articles, but narrow enough so that the articles are united by a common theme. Primary research articles can be accessed and downloaded by scientists or students with institutional access. If you require assistance accessing primary research articles, please feel free to email: brandon.tang@fsst.ca

A list of the article titles (along with the author list) should be submitted to you. Emphasize that the articles must be original research articles, not reviews, although the students can utilize review articles to aid with general understanding of the field. (An original research article contains new data and results addressing a particular research question, whereas a review integrates information from several original research articles pertaining to one topic.)

The students should read the articles and write a review on the basic findings. The review should include an introduction, the body (summary of the major findings), and a conclusion separated by headings.

**TIP:** To prevent students from reading the papers and writing the review at the very last minute (which will be very stressful), ask them to provide you with brief summaries (one paragraph max) for one paper every week.

Papers should be evaluated based on mastery of the material and clarity of writing. Exemplary reviews will be considered for publication in the Journal of Student Science and Technology.

**Breakdown of components for students:**

**Introduction:** Describe the field that you are studying, and explain why it is important. Provide the reader with the background information necessary to understanding the research articles. Maximum length is 500 words.

**Body:** Thoroughly discuss the articles that you have been assigned. For each article, explain the results and the interpretation of the results. You may separate your analysis of each paper with subheadings. Describe common findings and themes between the articles as well as any discrepancies. Maximum length is 1000 words.

**Conclusion:** Use this section to tie together the ideas presented in the different articles. You should also remind the reader why this topic is significant, and what questions have yet to be answered. Maximum length is 300 words.

**References:** You should list all of your references in ACS format in the order in which they appear in the report, and ensure that they are numbered. In-text referencing is also required; you should place a superscripted number corresponding to the referenced work at the end of the sentence that draws upon that work. Please include DOIs in your references.

**ACS FORMAT FOR JOURNAL ARTICLES:**

Author, A. A; Author, B. B; Author, C. C. Title of Article. Journal Abbreviation (italics) [Online if online] Year (boldface), Volume (italics), Pagination.

**MULTIMEDIA PROJECT PROPOSAL ASSIGNMENT GUIDELINES [FINAL PROJECT]**

**Overview**

Scientific publishing has become increasingly influenced by the digital age. Today, most research articles can be accessed online via literature databases or publishers’ websites. Publishers have also begun to incorporate multimedia into their standard publications. For instance, the publication of video abstracts along with manuscripts has become popular with many academic journals. The purpose of video abstracts is to increase the visibility of the authors and to engage the audience more deeply than possible on paper alone. In a video abstract, the authors generally highlight key findings and explain the conceptual significance of their work.

This assignment is a spin-off of video abstracts that allows students to (1) demonstrate understanding of a given scientific field, (2) develop
plausible experiments based on known scientific methods, and (3) express their ideas clearly and professionally through a video. This assignment is recommended as a final project, and students should be given at least eight weeks to complete it as it is demanding at the high school level. Groups of 1-4 students can work on this project as long as their topics of interest are fairly similar.

**For Teachers:**

There are several steps that need to be taken towards creating a successful video proposal.

1. **Obtaining background information (2 weeks)**

Students should review 2-3 papers (reviews are allowed) to obtain background information on a field of their choice.

2. **Designing one experiment (2-3 weeks)**

Based on the papers they have read, your students should come up with a specific question and design one plausible experiment to address it. We recommend that students consult a scientist mentor and receive feedback before proceeding with the video proposal. To be put in contact with these mentors, please email: brandon.tang@fsst.ca.

Students should review the following components of their proposal with both you and their mentor, if applicable:

- **Research Question**
- **Rationale for experiment/hypothesis** (i.e. why are you doing the experiment; what do you expect to happen?)
- **Method** (i.e. how the experiment should be carried out; includes techniques and experimental controls; details are not necessary)
- **Possible results and interpretation** (i.e. there should be at least two possible results for the experiment; the student should explain what each outcome means (i.e. supports/modifies/rejects hypothesis).

3. **Making the Video Proposal**

Each video should be 5-8 minutes long. Approximately half the time should be used to explain the background information and the other half should be dedicated to the student's experiment proposal.

While students should be encouraged to be creative with their videos, professionalism and clarity are top priorities. At the very least, a PowerPoint with diagrams and a voiceover can be managed. The following link to Cell’s best video abstracts can provide some inspiration, and should be shown in class: [http: // w w w . c e l l . c o m / video_guidelines](http://www.cell.com/video_guidelines)

**VIDEO STRUCTURE GUIDELINE FOR STUDENTS**

**Title Slide:** In the first few seconds of your video, you should display a slide with your proposal title and your name.

**Author information:** Briefly (<20 sec) introduce yourself and your inspiration for getting involved in this particular field of science. You should be on video in this segment, directly speaking to viewers.

**Description of Research:** Describe your chosen field of research. Provide viewers with major concepts required to understand the research, as well as recent advances in the field. You may use schematics or pictures to clarify your explanations and make the video visually appealing, so long as they are cited if they do not belong to you.

**Experiment Proposal:** Describe your experiment, making sure to cover the following points in the given order...

1. Previous research that leads up to your proposal
2. Your question and why it is important
3. Rationale for your experiment / hypothesis
4. Details for your experiment (i.e. experimental techniques and controls)
5. Possible results and interpretation

**Conclusion:** Wrap up your presentation very briefly. One sentence such as “My name is [...] and thanks for listening to my presentation on [...]” is sufficient.

Acknowledgements and References: Two concluding slides should follow the video proposal. The first slide should list references, and the second should acknowledge any individuals or organizations who provided guidance.

High quality video proposals will be eligible for publication in the Journal of Student Science and Technology. For instructions on how to use video editing software, see the accompanying text.
VIDEO EDITING HELP FOR STUDENTS

Overview

Video editing for the video proposal project is easy— you don’t need to be a master of advanced video editing programs such as Adobe After Effects, Premier, or Final Cut. There are several programs that are free and simple to use for both Mac and PC users. Basic video editing software comes preinstalled on computers running Mac OS (iMovie) or Windows (Windows Movie Maker). Although the following guidelines were written with Windows Movie maker in mind, they are broad enough that they should be informative to anyone using basic video editors such as iMovie, Cyberlink, PowerDirector, and Lightworks.

Step 1: Importing media

Upon opening the program, you will notice a tab on the main page that either reads “Import Media” or has the image of a folder with an arrow protruding from it. By selecting this tab, you can import all the images (figures, lecture slides, diagrams), video files (webcam or video camera recordings), and sound files (narration) necessary for your submission. All of these files will appear in your video library for easy manipulation.

Step 2: Arranging your files

At the bottom of the screen, you will see a timeline. By dragging your media onto this timeline, you can decide the order that images or videos will appear. For images, you can select the leading edge of its representation on the timeline and manipulate it to determine how long the image will appear in your presentation. Below the blocks that represent videos and images, there is a parallel timeline for sound files. Simply drag the sound files from your media library and place them below the visuals that correspond to your voiceover.

Step 3: Finishing touches

Add titles, transitions, and effects. As laid out in assignment, a title page is needed at the beginning and end to introduce your submission and cite references/acknowledgements respectively. Though you can add these as images or slides, the video editing software will also give you the option of creating these within the program. Under a tab labeled “edit” or along one of the menu bars, you will also have the option of introducing transitions between media files. Transitions are acceptable but should remain tasteful (avoid eccentric or distracting transitions).

Step 4: Publishing

Even basic video editors allow you to select the file extension and the level of compression of your final work. If you wish to publish your project in the Journal of Student Science and Technology, consult the guidelines online for video abstract submission when choosing these options. You will want your final submission to have an appropriate file extension as well as the highest quality graphics and sound without exceeding the cut off file size of 500 MB. You may want to publish a couple versions to get this just right.

For more in depth instructions for how to use iMovie (Mac users) or Windows Movie Maker

- Maker (PC users), please click the links below.
  - iMovie
  - Windows Movie Maker

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