

All the Right Questions	Grades 9 to 12 – Scientific Investigation Skills
<h1 style="color: #1a3d4d;">Lesson Plan</h1>	
<p>Learning Outcomes</p> <p>A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating)</p>	<p>Specific Expectations</p> <p>A1.3 identify and locate print, electronic, and human sources that are relevant to research questions</p> <p>A1.6 gather data from laboratory and other sources, and organize and record the data using appropriate formats, including tables, flow charts, graphs, and/or diagrams</p> <p>A1.7 select, organize, and record relevant information on research topics from various sources, including electronic, print, and/or human sources (e.g., websites for public health organizations, federal and provincial government publications, reference books, personal interviews), using recommended formats and an accepted form of academic documentation</p> <p>A1.9 analyse the information gathered from research sources for reliability and bias</p> <p>A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions</p> <p>A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)</p>
<p>Description</p> <p>Students will learn the principles of good experiment design, and then apply that knowledge to existing scientific or pseudoscientific works to evaluate their quality.</p>	

Materials

Materials can vary depending on the experiments students design. Work with your students to help them design a study for which you have the materials.

Introduction

Science literacy is a skill which can, and should be, honed and practiced. To have skill in science literacy is to be able to discern the quality of a scientific study or experiment, as well as the ability to understand how and why it is being communicated in a specific way.

Science literacy requires some familiarity with how a study or experiment should be designed and carried out. Some fundamental terms will be useful.

Qualitative	Research which uses comparisons or groupings instead of numbers.
Quantitative	Research which uses primarily measurements using a specific unit.
Validity	How accurately does the research measure what it intends to measure?
Variability	How much can the results be influenced by randomness?
Control Group	A group which is not subjected to a change in conditions, whose results are certain.
Peer Review	The process by which other experts in the same field review the work of a scientist before publication.
Replicability	If the research is repeated, with no changes to the methods, are the same results achieved?
Abstract	The section of a journal article which provides a very brief summary of the question and findings.
Methods	The section of a journal article which describes in detail how the results were achieved.
Results	The section of a journal article which describes exactly what the scientist found by doing the research.
Discussion	The section of a journal article in which the scientist explains what the results mean.
Conclusion	The section of a journal article in which the scientist explains what they think should be done or why the results are important.

What a credible piece of research looks like depends on the goal. Most qualitative research, for example, will be looking at a specific scenario in a specific time and place, and so its

perfect replicability may be less of an important factor; however, if it is not replicable, but the discussion and conclusion project the results to apply to a far greater scope, the research is not very credible.

There is not one simple checklist that will always apply when evaluating research for credibility. However, there are some questions we can ask and some things we can look for to put us on a good starting path.

1. Is it peer reviewed? Peer review is a process that exists to catch bad actors in a field, and to make sure that methods and results align with what would be expected in that field. A peer reviewed paper is more likely to be credible than one that isn't.
2. Who funded the research? If a cereal company produces research which suggests their brand is especially good for children's educational performance, for example, they have motive to fudge data or make leaps which aren't credible.
3. Has this study been replicated? If other, similar studies have achieved similar results, the study is more likely to be credible.
4. If the study has subjects, how big is the sample size? For example, if in a study with mice, six mice were used, chance has a much greater influence over the results. However, in a study with six hundred mice, chance is easily accounted for because it will be closer to its theoretical probability.
5. Is the study measuring what it says it is? For example, an experiment measuring whether the annual volume of rainfall impacts tree growth should be controlling other variables to make sure the tree growth is not also being impacted by things like sunlight or differences in soil. The discussion and conclusions should also follow logically from the results, and not make conjectures for which there is no evidence.

When it comes to science, we often hear about it first not by reading journal articles or studies, but through social media or news outlets. Part of science literacy is being able to find the source and understand it for yourself, but part is also understanding the way it is being communicated.

1. Bad actors can cite a study and cherry pick what they use to support their argument, even when the study itself, if read in full, directly contradicts that supposition.
2. Headlines are designed to draw clicks, and may be misrepresentative of the whole story, so always read the whole news article before drawing conclusions.
3. If a news article or social media post references a study, give the study at least a skim for yourself to see if it supports what the news article or post is claiming it does.
4. Use the SIFT method – before you share something, **Stop. Investigate** the source – is the author biased? Is the author representing the science accurately? **Find** better or additional sources – are multiple sources making the same or similar claims? **Trace**

the story to its source. Is there a journal article supporting the claim? Who first made this claim? What evidence do they have? If the source checks out in all these steps, then you can share the post.

Action

This activity can be done individually or in groups. You can choose to do as many of the parts as you want with your class.

1. Use the PowerPoint provided to guide students through the design of their own experiment.
 - a. Guide them to choose an experiment for which you have materials, or materials can be easily acquired.
2. Have students swap their experiment with that of a peer. Have them evaluate the credibility of the proposed research project.
3. Have students iterate their experimental design to address any problems uncovered in the review, and then conduct their experiment. Students should keep a journal of their methods throughout.
4. Have students write up their results in a format with an abstract, methods, results, discussion, and conclusion.
5. Have students swap papers, and write a news, blog, or social media post about the findings. They should write it in such a way that people will want to read it.
6. Swap a third time, and have students evaluate the post for how accurate it is to the paper.

Consolidation/Extension

Choose a journal article in a relevant topic to what you are studying in class. Distribute it to the students.

Sort the students into two teams, each arguing opposite sides of a debate. For example, if you choose an article about the impact of fracking on birds, have one group argue that the concern is overblown or exaggerated, and have one group argue that fracking should be halted immediately anywhere that birds live. They must each make three arguments based on something written in the paper for their side, whether that is what the paper itself is arguing.

The goal is to teach them how people can cherry pick arguments to misrepresent research for the sake of an agenda.

Additional Resources

<https://harmonysquare.game/en>

<https://harmonysquare.game/fr>

<https://app.crankyuncle.info/language>

<https://guides.lib.uw.edu/research/reputable>

<https://www.jstor.org/action/showAdvancedSearch>

Visit your local library website for access to a variety of journals and research databases.