 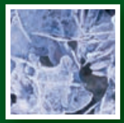  

A CLOSER LOOK:

Doing Project-Based Science

A CURRICULUM RESOURCE

Question, Investigate, Discover!

NOVA SCOTIA

A CLOSER LOOK:

Doing Project-Based Science

A CURRICULUM RESOURCE

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Contents

Introduction

In the modern classroom, students come from a variety of backgrounds with a variety of skills. In order to successfully accommodate the different needs of students, a teacher must incorporate multiple teaching strategies. This basic principle is true in all areas of curriculum and is one that may be challenging in science. Project-based science is a teaching approach that encourages students to explore science through research that incorporates their backgrounds, skills, and interests. It allows students to become real scientists and to truly use the scientific process to learn about the world around them.

This curriculum resource provides an introduction to project-based science and some basic steps that may be followed to incorporate it in the classroom. There are examples of a number of projects that may be used or modified to fit into a variety of classroom settings.

What Is Project-Based Science?

Project-based science, often referred to as "real science," is a science instruction method that has students and teachers completing projects in a fashion similar to the research methods of "real" scientists. Through individual and collaborative research, students are provided with the opportunity to construct science knowledge through hands-on, minds-on, self-directed experiences.

The project-based method encourages teachers and students to explore and examine a variety of different activities and situations that address different learning styles and cognitive strengths. Through this process, a number of science curriculum outcomes are easily addressed, as well as outcomes from other curriculum programs.

A project-based science activity can be designed to fit any science classroom. It can be a small activity that covers a few class periods, or it can be a full-course investigation that results in a project to be celebrated in a variety of ways, such as being presented in class, in science fairs, in an open house, at community events, at various science centres, or at any place where science is celebrated. Whatever the end result, project-based science activities all include the following common components.

- **A focus question or a driving question:** When students create a focus question, they become the key figure(s) in a project from the beginning. A clear focus question helps to organize the method that will be used to direct the research. The question is key here and is one of the most difficult parts of the process. The focus question also provides a reference point for reflection throughout the study. The question may be revised throughout the course of study as directed by the research.
- **Investigation:** In project-based science, the focus question leads directly to authentic problem solving through research, experimental design and operation, data collection and analysis, estimation, discussion and debate, group interaction, summarizing and drawing conclusions, and the refining and examination of the original question.
- **Artifacts:** Throughout the duration of a project, students will produce artifacts, such as a number of reports, devices, and displays, that show a true understanding of the focus question.
- **Collaboration:** Whether students work alone or in groups, collaboration will occur throughout a project-based exercise. Working in class, sharing new discoveries, questioning others' conclusions, and participating in classroom presentations allow students and teachers to explore avenues in their research that they may not follow on their own and to further expand the study of the focus question.
- **Technology and telecommunications:** Modern technology has expanded capabilities of investigating science in a wide variety of ways. Communication with professional scientists, discussions with other students from around the region or the world, and the accessibility of vast amounts of information allow students and teachers to completely explore the answers to their questions and share the information that they have collected.

The Benefits of Project-Based Science

Project-based science provides unique learning opportunities that are not found in traditional science lectures and laboratory classrooms. Learning like “real” scientists turns the table on science understanding and makes the student the constructor of knowledge. Some of the many benefits of a project-based approach to science instruction are

- addressing science, technology, society, and environment skills outcomes
- addressing language arts outcomes
- addressing mathematics outcomes
- the development of authentic learning and assessment practices
- the transfer of knowledge development from teacher to student
- the opportunity for teachers to become students and develop project skills along with their students
- the correlation of knowledge from physics, chemistry, biology, and other branches of science
- the multidisciplinary approaches to sciences
- the development of problem-solving and questioning skills
- the opportunity to enhance research skills and develop critical-thinking and evaluation skills
- the opportunity to collect and share knowledge in a number of formats addressing a variety of intelligences
- the opportunity to have a public celebration of science through presentations to the school, to parents/guardians, and to the general public
- the opportunity to integrate science with other curriculum areas such as art, mathematics, public speaking, and others
- the opportunity for teachers in different curriculum areas to work collaboratively on a project
- the ability to modify and adapt an individual’s project in order to accommodate his or her strengths and avoid weaknesses
- the introduction to “real” science practices

Incorporating Project-Based Science in the Classroom

Project-based science is a rewarding method of learning and teaching that allows students and teachers to interact in ways that are not common in traditional science classrooms. The intent is that teachers do and present their own projects and model the behaviour to their students. The teacher is always ahead of the students in the process of his or her project, so there is control over timelines, the opportunity to lead by example, and the chance to assess and examine students exploring science.

In a project-based science activity the role of the teacher changes from being a person who provides the knowledge to being a person who facilitates research. The teacher models the processes expected of the students, makes suggestions on the direction of student research, and encourages students to follow their successes and explain their questions. This offers teachers an opportunity to examine the content of their courses in a different light and helps students to be independent learners.

Teachers must fully adopt the project-based science concept when carrying out active research with their students. The teacher now facilitates the answering of questions. It is important for teachers to be aware of their students' progress throughout the entire investigation. Teachers can guide the students' research without controlling the topics, methods, or focus questions just by being aware of the current status of each project.

Planning

The initial organization of a project-based science classroom has traditionally been thought of as time consuming and labour intensive. However, once the initial guidelines are established, the process uses time effectively. When properly organized, a project-based activity will run smoothly and achieve its goals for all students, as well as provide a number of opportunities for student assessment. The following are some suggested steps for beginning project-based science in the classroom.

1. **Decide on the type of project.** Project-based learning can address short-term activities, such as exploring a specific topic in a unit or a complete unit. It may also be used as a culminating activity to summarize learning in a course. A public presentation allows the student to act like a scientist in presenting the work.
2. **Establish a timeline for the project.** No matter what type of project, a well-defined and modelled timeline for the activity is key to its success. When students are aware of time expectations they are less likely to fall behind. The teacher project and designated class time are important to help keep all students on task and to ensure that all are progressing in a timely fashion on their individual projects. A checklist can be created to track progress during the project. See Project Planning on page 13.

3. **Organize the teacher project.** The teacher must decide upon a project that will be carried out as a model for the students. By going step by step through a project with the class, a teacher will model the work habits expected of students as well as keep the class on time and on task. The teacher should always be a week, a day, or an hour ahead of the students.
4. **Determine the methods of evaluation that will be used.** Project-based science provides many opportunities for the evaluation of student work. Clearly stating the value of the project in the overall marking scheme, may motivate students to accept the challenge of a project and work hard to succeed. A clearly designed rubric should be created for updates and activities completed during project assessment, as well as a rubric for the final culminating activity. Some sample rubrics can be found in the Assessment and Evaluation section.
5. **Prepare a list of related resources containing project ideas.** Once the format of a project has been determined, create a list of possible resources (e.g., websites, materials, books) that will aid in the beginning stages of a project.
6. **Establish cross-curricular links with other teachers.** Project-based science requires a wide variety of skills. Students will not only be meeting science outcomes through the project process, but will also cover art, language, mathematics, and other course outcomes. Teacher collaboration in the planning stage of a project will allow for a broad-based assessment of student projects.
7. **Establish mentorship links.** Professional or academic mentorships are a useful tool in long-term research. Arranging for mentors before a project begins will assist in the initialization of a project and will provide someone to contact if questions come up through the process.
8. **Organize project showcase.** A public celebration of the project is part of project-based science. Whether the end result is a science fair or in-class presentation, time and space should be allotted to showcase project work. This includes the students' and the teacher's work. Booking a time and space well in advance will give a clear target date and allow students to envision how they might develop a final product.

How to Use Project-Based Science

Project-based science can be used to cover virtually any topic in the science classroom. It allows the teacher to cover a variety of skills, such as research, communication, and presentation skills, that are not always reached by traditional methods of science instruction. Project-based science should be used to bring the process of science (inquiry, problem solving, and decision making) to students. A project should include a discussion to establish focus questions, a specific timeline for research, and time for investigation. Creating a timeline and a bank of resources will make projects run smoothly. A well-planned project that is presented with enthusiasm will be sure to cover a number of science outcomes.

Finding a Focus Question

When a teacher or student begins a project, the focus question is often the most difficult, but the most important, part of project-based science. Spending time to interact with the students on the focus question development will pay off with better project results for students. When creating a focus question, students should consider the following:

1. Is the focus question clearly posed?
2. Does the focus question clearly direct research?
3. Can the focus question be completely investigated within the timeline of the research?
4. Can the focus question be answered with the resources available for research?
5. Is the question interesting to the person doing the project?

A student or teacher should answer yes to all of the questions above. The focus question will be the driving force of research and, therefore, should be considered carefully.

The benefit to students of a clear focus question is the fact that it directs research along one specific pathway. Many students find long-term projects difficult because they find the amount of information available to be immense. If a clear focus question is developed before the start of in-depth research, the student will have less difficulty with the massive amounts of information available on any topic. The focus question allows students to quickly sort through useful and non-useful information.

Keeping a Research Log

One of the best ways to keep a project running smoothly from start to finish is to keep a research log or journal. Research logs that are kept up to date will allow students to look back at what they have done, examine and reflect upon results, and change the direction of their future research. A research log should have two components that are kept up to date throughout the time of study.

The first part of a research log is the personal reflection on discoveries to date. Here students can examine what they have discovered, relate it to their current knowledge, and explore how it applies to their project. The reflection also provides students with an opportunity to sort through the information they have collected and filter out the parts that do not relate to their focus question, thus making the end goal of their research clearer. The entries in the reflection section should all be dated in order for the student and teacher to keep up to date on the research timeline.

The second part is the data. Regardless of whether or not the project is a study, experiment, or innovation, a student is going to collect data of one form or another. A well organized research log provides the student with a place to collect and analyze their data. The end result of a project should contain a conclusion based on the data but need not contain every piece of information collected throughout the course of study.

Research logs provide an excellent opportunity for students to assess their work to date and use this assessment to further develop their study. The logs also provide the teacher with a tool to assess how well the students worked on their projects from start to finish.

A research log should be maintained from day one of a project until the project is completed. Teachers may set up the format of the research log for their students, and all research logs should be organized in a way that fits the topic or method of study chosen by the student and teacher.

Project Planning

This section includes sample timelines for a topic project, unit project, and long-term project. Each timeline includes information about the activity, comments on what may happen, and a checklist to help focus the project.

Topic Project

Topic projects are short-term activities that are designed to quickly investigate a particular subject in a science classroom. This type of project allows students to obtain some background information about a topic before the class completes a full investigation. These activities may be used to introduce a chapter or to summarize a recently completed topic area.

Four one-hour periods will be set aside to complete the project.

Period	Activity	Description	Checklist
1	Introduction, class discussion, and topic research	Students should be given information about the topic and the opportunity to explore and create focus questions.	By the end of the period, all students will have a focus question for their research.
2	Focus question refinement and data collection	Students will review the focus question suggestions provided by the teacher and continue research with the focus question as the core of their research.	By the end of the period, all students will have a complete focus question, an overview of the data they haven't collected yet, and a summary of the information collected so far.
3	Research completion	Students will finish their data collection and finalize plans for reporting their discoveries.	By the end of the period, all students will have a summary of their discoveries and a description of the artifacts they will use to share the information with the class.
4	Project completion	Students will prepare the artifacts for their projects.	By the end of the period, all students will hand in a completed project report and artifacts.

Unit Project

This sample timeline may address all or part of a unit. The project may be used to examine topics that are more difficult to cover using traditional methods or to provide a variation from traditional science teaching methods.

Nine class hours will be set aside over the next six weeks to complete and present the following project.

Period	Activity	Comments	Checklist
1	Introduction and topic research	Students should be given information about the topic that is being covered and the opportunity to explore and create focus questions.	By the end of the period, all students will have a rough draft of their focus question.
2	Focus question refinement	Students should share their focus questions with the teacher and other students and begin to outline their project design.	By the end of the period, all students will have a finalized focus question and a draft outline of their project design.
3	Research tools and project design	Students will begin their research by locating resources and creating a bibliography of sources they plan to use. Students will also finalize their project design.	By the end of the period, all students will have a completed project design and a list of five resources they will have on hand to research their focus question.
4	Research and experimental design and setup	Students will continue research into their focus question and, if appropriate, set up their experimental equipment in order to complete their study.	By the end of the period, all students will have a collection of data or summarized information that describes their focus question.
5	Continued research and experimentation	Students will continue with their research and data analysis.	By the end of the period, all students will have a record of collected data and what research has yet to be completed.
6	Research completion	Students will conclude their research and data collection.	By the end of the period, all students will have completed all research and experimentation necessary to complete their project.

7	Project organization	Students will have all of the materials necessary to bring their project together as a cumulative reporting of their study. This may include papers, display posters, or a website.	By the end of the period, all students will have a completed project.
8–9	Presentations	Students will present their projects to their teacher and their peers.	By the end of the period, all students will have presented to and/or evaluated the projects of their classmates.

Long-Term Project

A long-term project can address a multitude of science topics. A long-term project requires time and commitment both from the teacher and the students and should be valued to reflect its importance. As with any project-based science activity, the teacher should participate by completing a project with the students. This helps the students keep on task and interested in the work and provides the teacher with the opportunity to demonstrate skills such as research methods, experimental design, and data collection that are not always involved in traditional science teaching.

One period of each Friday will be set aside for the long-term project for the science fair. In the 16th week there will be a public celebration of the projects (Science Night, Open House, etc.).

Week	Activity	Comments	Checklist
1	Introduction and topic research	Students should be given information about the topic that is being covered and the opportunity to explore and create focus questions.	By the end of the period, all students will have a rough draft of their focus question.
2	Focus question refinement and project design	Students should share their focus questions with the teacher and other students and begin to outline their project design.	By the end of the period, all students will have a finalized focus question and a draft outline of their project design.
3	Research tools and project design	Students will begin their research by locating resources and creating a bibliography of sources they plan to use. Students will also finalize their project design.	By the end of the period, all students will have a completed project design and a list of five resources they will have on hand to research their focus question.

Week	Activity	Comments	Checklist
4	Research list preparation	Students are to complete and pass in a list of resources and a description of how these resources will be applied to their research question.	By the end of the period, all students will have passed in a list of resources they plan to use in their study.
5	Project design completion	Students are to complete a concept map for their project with suggested timelines, necessary equipment, resource materials, and experimental or laboratory components.	By the end of the period all students will have passed in a concept map with timeline for their project.
6–9	Research and experimentation	Students will carry out research and experiments to evaluate their hypothesis and reassess their discoveries and predictions.	Students will maintain a data log that records their discoveries and refinements to their project.
10	Progress report	Students will be reminded that they are two-thirds of the way through their project and will prepare a progress report.	By the end of the period all students will have passed in a progress report that includes a summary of discoveries, changes to the project design, new resources, and a diagram or description of the display layout for the project.
11–12	Continued research and experimentation	Students will begin to finalize their projects by assessing the discoveries made to date and deciding what needs to be done to complete the project. Students will also correlate and analyze data collected.	Students will maintain a data log that records their discoveries and refinements to their project.
13	Report completion	Students will put the finishing touches on their written reports and prepare 50-word summaries of their discoveries.	By the end of the period, all students will have passed in their project reports and 50-word summaries.

Week	Activity	Comments	Checklist
14	Display completion	Students will put the finishing touches on their project displays and seek out advice from teachers and fellow students.	By the end of the period, all students will have passed in their completed project display.
15	Project sharing	Students will set up their projects to be presented at a science celebration.	By the end of the period, students will be prepared to present their projects.
16	Public celebration	Students will present their projects to judges, classmates, teachers, and/or the public.	By the end of the day, students will have presented their work in a public forum.

Assessment and Evaluation

The assessment of a project-based science activity provides teachers with a unique opportunity to evaluate student learning in science. There are a variety of science, technology, society, and the environment (STSE), scientific skill, and knowledge outcomes that may be covered through a project. Providing students with the opportunity to assist in the creation of evaluation tools for projects gives them an opportunity to examine how to design a project that fits the project they are working on.

Assessment *of* Learning

Assessment *of* learning is the method of evaluation that is most familiar to teachers. This type of assessment involves looking back at what students have covered and determining how well they have internalized the information. The completed project should represent the learning of students at all stages of project development. A good rubric or set of rubrics makes the assessment of a student project effective and quick to complete. Rubrics are useful tools in the final assessment of a science project. Rubrics should include the assessment of all aspects of the student project, including focus question quality, research effectiveness, effort, and the overall quality of all artifacts produced through research.

Assessment *for* Learning

Assessment *for* learning involves the use of effective assessment tools to help develop knowledge through the act of assessment. A project-based investigation that includes clearly focused assessment guidelines that involve students in all aspects of the assessment creates unique learning opportunities for both students and teachers. Students should be involved in the creation of rubrics, the creation of questions based on their research, and the evaluation of their work from start to finish. The chance to be part of the assessment of a project from start to finish empowers students and creates conditions that allow them to capitalize on every learning opportunity provided by a project.

Rubrics

A complete scoring rubric that addresses all aspects of a project is one of the most effective and efficient ways to evaluate a project. A rubric should be developed with students and should be completed by both students and teachers throughout the course of a project. There are also a number of online resources available that may be helpful when developing a rubric for a specific project.

Assessment Examples

EXAMPLE 1: PROJECT ASSESSMENT CHECKLIST

Teacher Name: ______________________________ Student Name: ________________________

Reviewer Name: _____________________________ Date: ______________________________

	Focus Question The student has posed a clear focus question for which results can be obtained by the student during the time period available.
	Background Research The student has proposed a well-structured answer to their question and included information from at least five different sources.
	Co-operative Groups The student participated well in all parts of the project and was actively involved in the project organization and completion.
	Experimental Research The student's experiments are well thought out, well designed, safe, and important to the conclusion of their research.
	Experiment Work The student was an active participant in all experimental work and completed all activities safely and neatly.
	Relating Concepts The student has prepared a well-structured report and display that traces the pathway of the development of their final conclusion. The conclusion involves information from a wide variety of sources, all of which are relevant to the conclusion.

EXAMPLE 2: SCORING RUBRIC (FOR STUDENT AND TEACHER)

Teacher Name: ______________________________ Student Name: ________________________

Category	4	3	2	1
Idea	The student independently identified a question that was interesting to the student and that could be investigated.	The student identified, with adult help, a question that was interesting to the student and that could be investigated.	The student identified, with adult help, a question that could be investigated.	The student identified a question that could not be tested/investigated or one that did not merit investigation.
Question Development	The student independently developed a focus question well substantiated by a literature review and observation of similar phenomena.	The student independently developed a focus question somewhat substantiated by a literature review and observation of similar phenomena.	The student independently developed a focus question somewhat substantiated by a literature review or observation of similar phenomena.	The student needed adult assistance to develop a focus question or to do a basic literature review.
Description of Procedure	Procedures were outlined in a step-by-step fashion that could be followed by anyone without additional explanations. No adult help was needed to accomplish this.	Procedures were outlined in a step-by-step fashion that could be followed by anyone without additional explanations. Some adult help was needed to accomplish this.	Procedures were outlined in a step-by-step fashion but had one or two gaps that require explanation even after adult feedback had been given.	Procedures that were outlined were seriously incomplete or not sequential, even after adult feedback had been given.
Data Collection	Data was collected several times. It was summarized, independently, in a way that clearly describes what was discovered.	Data was collected more than one time. It was summarized, independently, in a way that clearly describes what was discovered.	Data was collected more than one time. Adult assistance was needed to clearly summarize what was discovered.	Data was collected only once and adult assistance was needed to clearly summarize what was discovered.

Category	4	3	2	1
Summary/ Conclusion	The student provided a detailed conclusion clearly based on the data and related to previous research findings and the hypothesis statement(s).	The student provided a somewhat detailed conclusion clearly based on the data and related to the hypothesis statement(s).	The student provided a conclusion with some reference to the data and the hypothesis statement(s).	No conclusion was apparent, or important details were overlooked.
Student Participation	The student participated actively in the creation, development, and all research aspects of the project.	The student participated actively in parts of the project with which they felt comfortable.	The student participated periodically in the research aspects of the project.	The student did not participate in the development of the project.

Curriculum Links

Mathematics

Project-based science activities create opportunities for cross-curricular links between mathematics and science. The collection and analysis of data meet a number of outcomes in various mathematics programs. The collection, presentation, and analysis of data are a key curriculum outcome throughout mathematics from primary to grade 12. This type of analysis is easily incorporated into a science project and can be carried out in a number of ways depending on the project. Appendix F provides an introduction to data analysis for science projects and includes descriptions of methods to cover a number of the pattern recognition and statistics outcomes set out in the Nova Scotia Department of Education mathematics curriculum.

English Language Arts

A key component of any project-based initiative is the presentation of discoveries to the teacher, the class, or the general public. The presentation provides an opportunity to develop cross-curricular links between science and English language arts. Presentations of research may include reports, posters, books, oral reports, or any other method of presentation developed by students and teachers. Involving the English language arts teacher in the development of a project can strengthen the results in all subject areas.

Possible tools that may incorporate language arts skills in science projects include the following:

1. **Literature Review** A literature review allows for the examination of various different perspectives on a research topic. It assesses the student's ability to summarize research articles and allow them to initially investigate a research topic from the point of view of others.
2. **Project Summary** A project summary is a critical writing exercise that encourages students to examine their research, collect the most important information, and write it in a way that is understood by all of the people who will be listening to the presentation or reading the report of the research.
3. **Research Paper** A project that includes an in-depth research paper involves the collection and analysis of a large body of work related to a given topic. The paper may include article summaries, data descriptions, introduction and conclusions, and other aspects of critical writing.
4. **Book Review** A book review can serve as a launch pad for a long-term research project. It can also provide a student with information for applications of their topic in everyday life.

Appendices

Appendix A: Sample Teacher Project

INTRODUCTION

This appendix includes a sample teacher-produced project. By effectively modelling a project from beginning to end, the teacher helps students understand the process and development involved.

The teacher project provides a teacher with a unique opportunity to guide student efforts without controlling the direction or methodology of student research. The teacher is always one step ahead of the student and uses the project to highlight where a student should be with their research as time passes. When the teacher does the project along with the students, the teacher may choose to look into a specific aspect of the curriculum that may not otherwise be explored.

The following teacher-designed project represents an investigation that a teacher conducted. Remember that projects should have a clear focus question with research directed at the focus question. Once a sample teacher project has been completed, it may be used again in the future or as the foundation of a new project for further study.

Photoelectric Effect—Which One Will It Be? (Physics 12)

TIMELINE AND OBJECTIVE

This 12-week project investigated a variety of methods of presentation of the photoelectric effect. The goal was to determine what method of presentation would be most effective with Physics 12 students.

INTRODUCTION

The year 2005 was declared the World Year of Physics to mark the 100th year since Einstein published his theory of special relativity in 1905. In that year, Einstein also worked on other areas of physics, including Brownian motion and the photoelectric effect. Einstein received the Nobel Prize for his work with the photoelectric effect in 1921. This was his only Nobel Prize.

The photoelectric effect is a topic that is also discussed in Physics 12. It is one that my students often have difficulty getting a visual perspective of, and thus, they sometimes have difficulty truly understanding the concept.

In the summer of 2005, I was introduced to a simulation device that would mimic what is seen in the photoelectric effect using a simple circuit board and some light-emitting diodes (LEDs). The use of a simple device to show an abstract concept intrigued me, so I decided to study it further.

FOCUS QUESTION

What is the best way to present the photoelectric effect as a concept to students?

I think that with some time, effort, and research, I will be able to build a photoelectric simulator. This device will clearly illustrate the physical aspects of the photoelectric effect.

METHODS/PROCEDURE

I discussed the concept with some other physics teachers and tried to find some plans on the Internet. Through research and some trial and error and investigation, I found three new tools to demonstrate the photoelectric effect to Physics 12 students.

In the analysis of each of the tools, the key things to look for were the ease of use and understanding, the relationship to the effect showing that the amount of electricity depends on the colour of light that is striking an object (not the intensity or brightness), the ability to collect and analyze data from the simulation, and the overall appearance and use of the devices.

The Photoelectric Effect

The photoelectric effect is a phenomenon that was first discovered in the 1870s. The fact that certain metals will give off electrons when struck by light was widely accepted, but the reason for the emission of electrons was unknown. Classical physics would say that the more energy in the light, the more likely that electrons will be emitted from a surface. Research into the photoelectric effect proved different however. The intensity of the light did create larger currents, but only if the current existed in the first place. The experiments of a number of scientists showed that the most important factor in getting a metal to emit electrons was the wavelength (colour) of the light. If the wavelength of the light source was too large, there would be no current created, regardless of the intensity of the light. This was the first discovery. Further research led to the discovery that if a voltage is applied to the circuit, the current can be stopped. The stopping potential was something that allowed for a quantitative analysis of the photoelectric effect to determine Planck's constant (6.636×10^{-34} Js).

Research

In the course of my investigation I examined three ways to determine the value of Planck's constant. There are a variety of devices and technologies out there that may be used to model the photoelectric effect. All have their advantages and disadvantages. In evaluating each method, I looked for the pros and cons of each in order to determine which method may work well in my classroom.

Part 1: Internet Java Applet

This applet was found on the *LearningOnline Network* website (http://lectureonline.cl.msu.edu/~mmp/kap28/PhotoEffect/photo.htm).

This is an Internet-based demo that allows you to change a number of properties to explore the photoelectric effect. There is a basic set of instructions to follow, and control sliders for voltage, intensity, and wavelength (colour) are available to manipulate. As changes are made to these properties, the applet visually displays the creation of a photoelectric current.

Pros

1. It is very easy to manipulate and see the changes.
2. A set of easy-to-follow instructions is available.
3. Colour changes are clear, and the effects of changing intensity, colour, and voltage are accurately displayed. This is a good overview of the basics of the photoelectric effect.
4. Conclusions derived by the historical study of the photoelectric effect can be determined using this visualization.
5. Most students could access this activity either at home or school over the Internet.

Cons

1. The instructions provided by the website are too simple, and there are no instructions that allow students to quantitatively examine the graphs and calculations necessary to evaluate the photoelectric effect.
2. A teacher would have to put some time into creating a worksheet for students to fully evaluate the photoelectric effect.
3. The lack of hands-on interaction may lead some to believe it is the software, not the physics, that is creating the effect.
4. There is a typo in the word “gap” in the text of the instructions. Perhaps there are other errors.

Part 2: Physics FX Software

Physics FX is a software package that has a number of physics demonstrations for students to evaluate. The demonstrations have a strong visual aspect that may make it easier for some visual learners to describe the demonstrations. The software comes with a binder full of activities to go along with the demonstrations. The activities are well laid out and very specific in their references to the demonstrations. The photoelectric effect demonstration has voltage, intensity, and wavelength controls that allow students to fully examine all of the properties that affect the electricity released by photoelectric metals.

Pros

1. It is very easy to manipulate the controls and see the changes with this software.
2. A complete set of three investigations is included.
3. The colour changes are clear, and the effects of changing intensity, colour, and voltage are accurately displayed. This is a good overview of the basics of the photoelectric effect.
4. The conclusions derived by the historical study of the photoelectric effect can be determined using this visualization.
5. The data tables for quantitative analysis seem to be easy to understand, and students should be able to fill them in without difficulty.

Cons

1. Some of the activities may be too in-depth. It may be necessary to create a graphic organizer to simplify the activity for classes.
2. The lack of hands-on interaction may lead some to believe it is the software, not the physics, that is creating the effect.
3. If a student does not pay careful attention to all of the data being presented, they may have difficulty completing the activity.

Part 3: LED Photoelectric Effect Simulator

Light-emitting diodes (LEDs) are small, efficient light sources that give off one only colour of light when electricity passes through them. This hands-on demonstration device allows students to manipulate the voltage being applied to the LEDs in the device in order to get specific LEDs to light up. As the voltage increases, the LEDs light up in order from red to violet. Using some creative calculations, the energy change as related to frequency can be determined.

My original plan was to try to build a device to set up this simulation. I got a start on it and found a small relationship between voltage and the colour of light given off. The lack of access to coloured LEDs made further investigation difficult. A trip to an electronics store will allow me to build one in the future. I did get a slightly more expensive model on loan from a local university.

Pros

1. This hands-on activity lets students play with the device they are manipulating and see light changes, not just interpret them on a computer.
2. It is easy to manipulate, measure, and calculate the changes that are occurring in the circuit.
3. Students can determine an estimate of Planck's constant that is reasonably accurate.

Cons

1. Creative mathematics is necessary to derive the constant.
2. There are no clear instructions on how to measure the effect, so an instruction sheet must be created.
3. Students are not able to change the metal, intensity, or wavelength of light, thus they are only looking at the voltage variable in the investigation.

CONCLUSIONS

Through the course of the investigation, I discovered a number of things. One of the first things was that I needed the skills to design a device to model the effect. Perhaps with some more time, I may have been able to figure it out.

Another important thing that I discovered is that there are a variety of ways to investigate this effect. I heard of two other methods involving spreadsheets and an expensive piece of equipment, however I did not get to study them.

In relation to my hypothesis, I discovered that a device could be built by me or my students. It would cost a little to buy the parts, but once the design is finalized, students could do it. This device would act as an effective simulation for the effect of changing voltage in a photoelectric system.

Overall, my study is inconclusive. I believe that the Physics FX model is perhaps the best method of instruction for the photoelectric effect in grade 12, but until all three methods are tested in a class, I can draw no clear conclusion.

Appendix B: Classroom Projects

Sample Project 1: Weather (Science 1)

This project may take two to three weeks. Before starting this investigation, talk about the introduction with the students and answer questions they have about weather. The introduction will set the foundation for the students' work. This project can be don by individuals or in groups.

Students at this grade level will need teacher guidance and support as they progress through the steps. Students should keep their materials for this project in one area/container for easy access when they return to the project.

INTRODUCTION

Each day as you get ready for school, what you wear is affected by the weather outside. Your choice of clothing depends on if it is warm or cold, if it is sunny or cloudy, or if it is rainy or snowy. The weather means lots of different things to different people, and how we get ready for it depends on what we are doing each day.

TIMELINE

Step	Activity	Description	Checklist
1	Introduction, class discussion, question(s) selection	Describe the weather of your favourite season. Write three questions about why the weather is the way it is in your favourite season.	By the end of this step, each individual/group will have collected or drawn five pictures showing the different effects and changes due to the weather of their favourite season. Create three questions to investigate.
2	Question(s) investigation	Come up with answers to the questions posed in step one. Use available materials and expertise to complete your questions.	By the end of Step 1, each of the three questions posed in step one should be answered.
3	Measuring and comparing weather	Use descriptive words to compare the weather in two different seasons. Then examine the weather measurement tools—thermometer, rain gauge, and anemometer (wind speed device)—and predict which property of the weather they measure.	By the end of this step, collect or draw six pictures (three from the two seasons) that show the weather in different seasons. Match the measurement tool to the appropriate picture.

Step	Activity	Description	Checklist
4	Inside and out	Use the thermometer and annemometer to measure the temperature and wind speed inside the school. Then go outside and repeat the measurements.	By the end of this step, record the weather collection data.
5	Project completion	Collect all of your artifacts and put them together in a weather poster to share with the class.	By the end of this step, each individual/group will pass in a completed poster.

Sample Project 2: Animals (Science 2)

INTRODUCTION

"Animals" is a week-long project where students will examine the habitat and life activities of an animal native to Nova Scotia and one native to the African plains.

Throughout the week, check on the progress of the assignment and let students know where they should be in the project.

PROJECT OUTLINE

Select one animal that lives in Nova Scotia and a similar animal that lives in Africa. Prepare a poster that compares the daily lives of the two animals.

PART 1: FOOD

The white-tailed deer and the impala are two similar animals that live in two completely different parts of the world. They live many miles apart, but live very similar lives. One thing they have in common is the food they eat.

	White-Tailed Deer	**Impala**
Favourite Food	Corn, grass	Grasses
Other Foods	Leaves, flowers	Leaves, flowers, and shrubs
Predators	Bobcats, cougars, coyotes, stray dogs, humans	Lions, leopards, hyenas, wild dogs, cheetahs, humans

PART 2: HABITAT

The white-tailed deer and the impala live in very similar habitats and are affected by many of the same factors in their environments.

	White-Tailed Deer	**Impala**
Habitat	Wooded areas near fields, meadows, or orchards	Grasslands near wooded areas and sources of water
Appearance	Brown coat, white belly, and white tail	Brown coat (2 shades), white belly, and white tail with black stripes
Antlers	Multi pointed, smooth antlers that increase in size and point number with age and are found only on males	Single pointed, spiral marked antlers that increase in size with age and are found only on males

PART 3: LIFE CYCLE

	White-Tailed Deer	Impala
Females	Able to have babies after six months and give birth to one to four fawns each spring	Able to have babies after one year and give birth to one fawn each spring and one fawn each fall
Males	Able to have babies before one year of age, but do not often breed until older	Able to have babies after one and a half years
Life Expectancy	If not killed, can live up to 20 years	If not killed, can live up to 15 years

PART 4: PROJECT PRESENTATION AND DISCUSSION

Students will present the project discoveries and posters to the class. Each presentation will include the information collected. Students should be able to identify where the animals live on a world map/globe. They may do a question-and-answer session with the class.

Sample Project 3: Atoms and Elements (Science 9 Unit Project)

INTRODUCTION

Encouraging students early on to determine the type of project they will be working on will help them plan their methods of research that will lead them to answer their focus question.

This project may be used to cover the outcomes for the chemistry section in Science 9. The unit project would be completed and then followed up by some teacher-based review to complete the unit. The project should be designed using the criteria below.

Throughout this project, assessment will be based on the aspects and artifacts produced to reflect learning. Upon completion of the project, students will be expected to present findings and pass in

- a visual display that summarizes discoveries
- an investigation report related to the topic (The teacher may help groups prepare if needed.)
- an oral presentation to the class of the discoveries
- a graphic organizer for classmates to record information from the study
- a completed self-assessment and logbook that reflects work throughout the project

TIMELINE

Eight hours or more may be needed to complete this project, plus two classes for in-class presentations of student work.

Step	Activity	Description	Checklist
1	Introduction and topic research	Analyze your topic using your textbook and other resources and begin to frame out the questions you will need to answer to complete your project.	By the end of this step, all students will have a rough draft of their focus question(s).
2	Focus question(s) refinement	Evaluate your focus question(s) from last class and identify the important factors involved in finding the answers to your question(s).	By the end of this step, all students will have a finalized focus question(s) and a draft outline of the project design.
3	Research tools and project design	Locate some resources needed to complete the research and answer the focus question(s). Design a method to answer the question(s) posed.	By the end of this step, all students will have a completed project design and a list of five resources they may use to research their focus question(s).

Step	Activity	Description	Checklist
4	Research and investigation design and set-up	Continue the research and set up materials/equipment to be used in the project.	By the end of this step, all students will have a collection of data or summarized information that describes their focus question(s).
5	Research day	Complete a self-designed or teacher-designed investigation related to the topic.	By the end of this step, all students will have recorded collected data and identified research yet to be completed.
6	Research completion	Continue the research and investigation work.	By the end of this step, all students will have completed the research and investigation necessary to complete the project.
7	Project organization	Put the finishing touches on the project and get prepared for presentation. Completed work should include the deliverables agreed upon by students and the teacher.	By the end of this step, all students will have completed their projects.
8	Oral presentations	Present the projects to the class and hand out activity sheets for all to complete.	By the end of this step, students will have presented to, and/or evaluated the projects of, their classmates.

RESEARCH GROUPS AND TOPICS (ATOMS AND ELEMENTS)

Group 1: The Periodic Table—its creation, structure, development, and application throughout history

Group 2: The Structure of the Atom—the history, development, and application of atomic theories

Group 3: Classification of Matter—groupings of the different types of materials found in the chemical world around us

Group 4: The Kinetic Molecular Theory

Group 5: Acids and Bases

Group 6: Chemical Safety and WHMIS

Group 7: Chemical Formulas and Chemical Equations

Group 8: MSDSs: Material Safety Data Sheets

Group 9: Careers in Chemistry

Group 10: Chemical and Physical Changes

Group 11: Metals and Non-metals in the World around Us

Sample Project 4: Viruses (Biology 11)

INTRODUCTION

A common misconception is that a common cold can be caught in a variety of ways. The fact is, the only thing that causes a cold is a virus. A biological virus is similar to a computer/technological virus in that a virus is inserted into the code of a body (or machine) in order to make more copies of the code. Without the body, the code will stop replicating. This project examines a number of viruses and how replication affects the bodies that host them.

TIMELINE

At the end of each step, each student/group will give an update of their discoveries. The completed project will be presented to the class.

Step	Activity	Description	Checklist
1	Introduction, topic research, and focus question(s)	Select a virus and conduct introductory research on it. Decide on what aspect of the virus to research and create a focus question(s) for the study.	By the end of this step, each group will pass in a preliminary focus question(s) and a list of at least three resources that may be used.
2	Focus question refinement and project design	Evaluate the focus question(s) based on research. Plan the format of the final presentations.	By the end of this step, each group will pass in their finalized focus question(s) and a concept map that outlines the entire project.
3	Research	Continue research and finalize data collection.	By the end of this step, a paragraph summary of discoveries to date will be submitted.
4	Project completion	Finalize your project for class presentation. Be sure that you have answered your focus question and that all of your information relates to your topic.	By the end of this step, students will have finished all of the required research and decided upon the finishing touches for their project(s).
5–6	Presentation	Display/present projects to classmates.	Pass in completed projects.

RESEARCH TOPICS (VIRUSES)

- H5N1
- HPV
- HSV-1
- HSV-2
- H1N1
- H3N2

Sample Project 5: Organic Chemistry (Chemistry 11)

INTRODUCTION

One of the biggest issues in Canada and around the world during winter is the cost of fuel. It is hard to escape news reports about the cost of gasoline, natural gas, and home heating fuel. All these fuels are different forms of hydrocarbons. Hydrocarbons are compounds made from hydrogen and carbon and, in certain cases, other non-metals. For this project, students will be examining a topic related to the types, use, and/or preparation of organic compounds. This project can be completed individually or as a group.

TIMELINE

At the end of each step, each student/group will be expected to give an update of their progress. The completed project will be presented to the class.

Step	Activity	Description	Checklist
1	Introduction, topic research, and focus question(s)	Select a class of organic compounds from the beaker at the front of the classroom and do some introductory research on the class that you have selected. Decide on what aspect of the chemical you wish to research and create a focus question(s) for your study.	By the end of this step, pass in a preliminary focus question(s) and a list of at least three resources that may be used.
2	Focus question(s) refinement and project design	Evaluate your focus question(s) based on your research and plan the final project format. Begin data collection.	By the end of this step, pass in focus question(s) and a concept map that outlines the entire project.
3	Research	Continue your research and finalize data collection.	By the end of this step, pass in a paragraph summarizing the progress to date.
4	Project completion	Finalize your project for class presentation. Be sure that you have answered your focus question(s) and that all of your information relates to your topic.	By the end of this step, students will have finished all of the required research and decided upon the finishing touches for their project.
5	Presentation	Display/present your projects to your classmates.	Pass in completed projects.

RESEARCH TOPICS

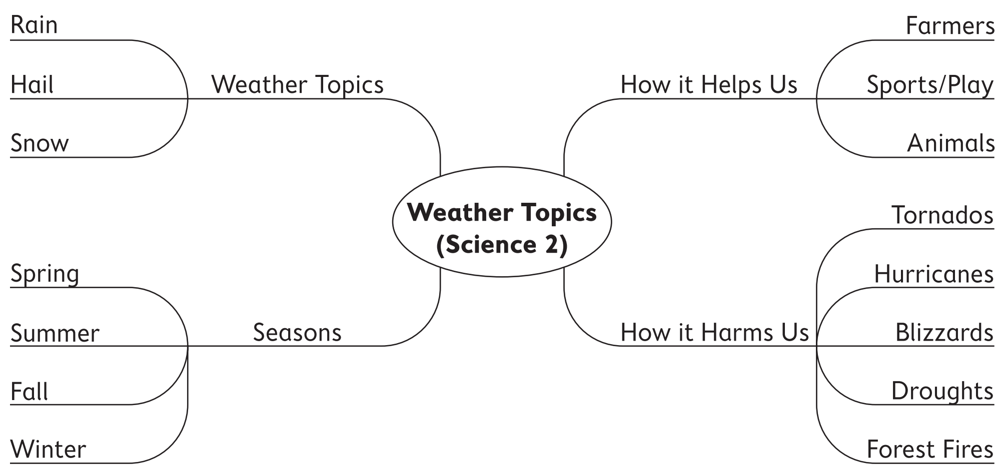
- Acids and Esters
- Alcohols and Carboxylic Acids
- Aldehydes, Ketones, and Ethers
- Alkyl Halides, Alcohols, and Ethers
- Amines, Carboxylic Acids, and Amides
- Aromatic Hydrocarbons
- DDT, CFC's, and PAH's
- DNA and RNA
- Fossil Fuels and Global Warming
- Petroleum Refining
- Plastics and Recycling
- Sugars

Appendix C: Graphic Organizers

Graphic organizers are tools that will help both the student and teacher visualize the goals, products, and methods of research for a project. It may be helpful to model the use of organizers or initially complete them as a group.

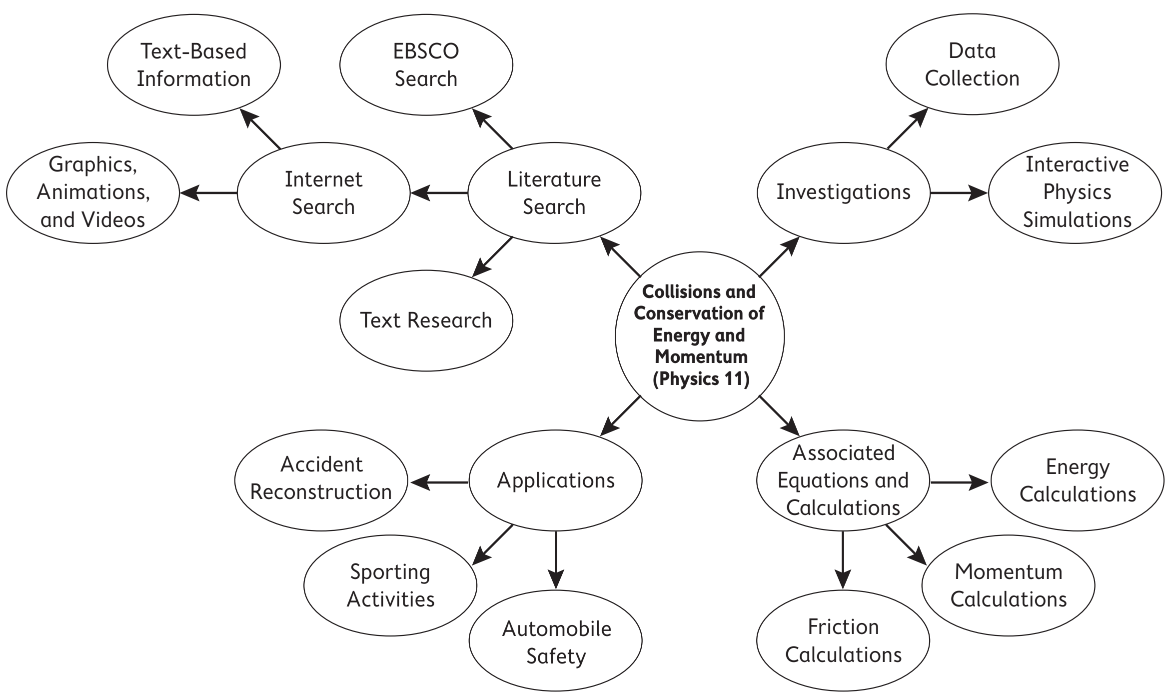
Example 1: Topic Organizer

This organizer can be completed by the class as a group to help divide topics amongst students and give a general overview of the collective projects.



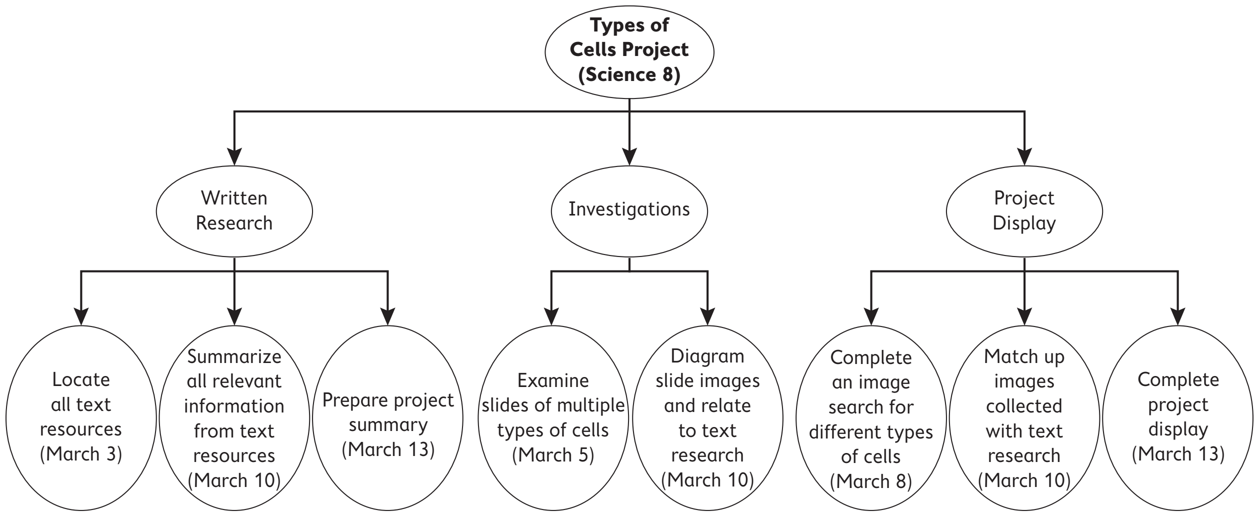
Example 2: Project Organizer

A student can use this organizer to help map out their project goals and the methods that they will use to complete their project.



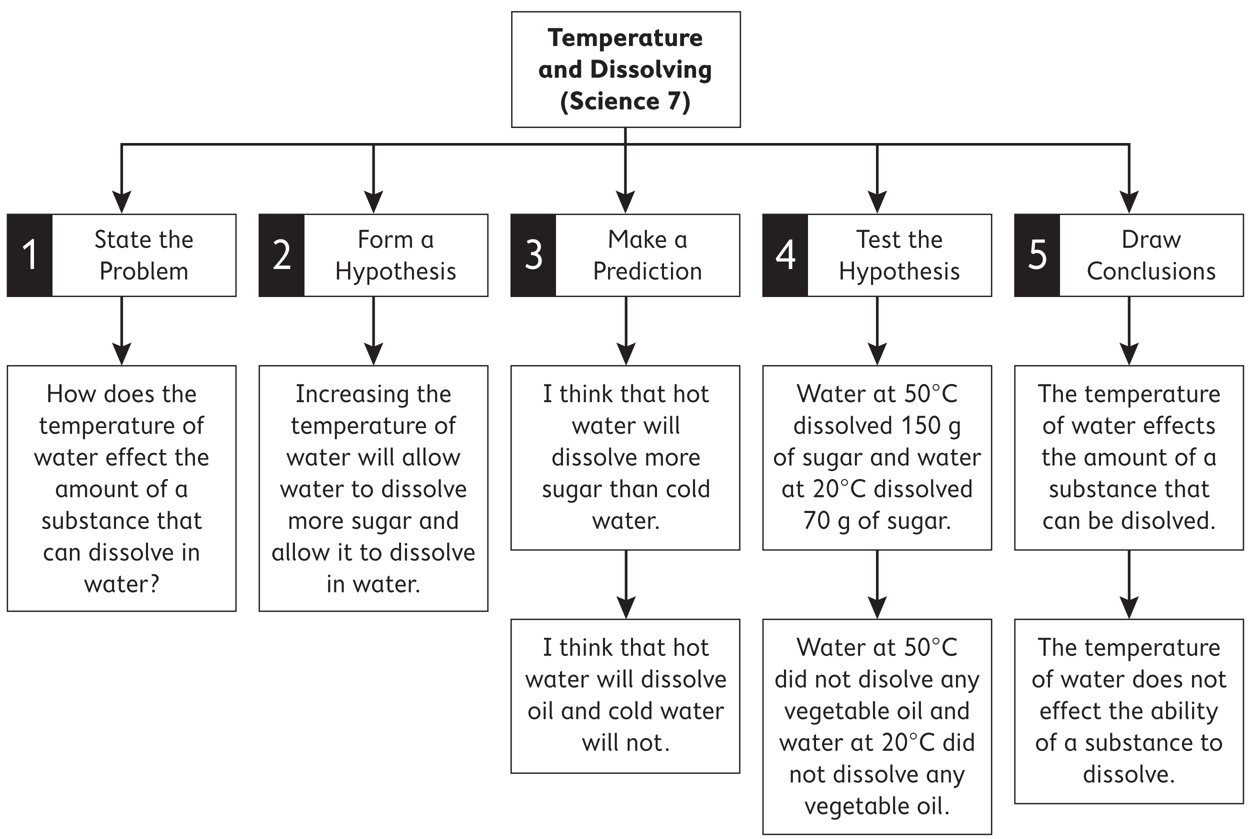
Example 3: Project Timeline

This organizer can be used by a student or a class to clearly map out the expected completion dates for all of the activities involved in a project.



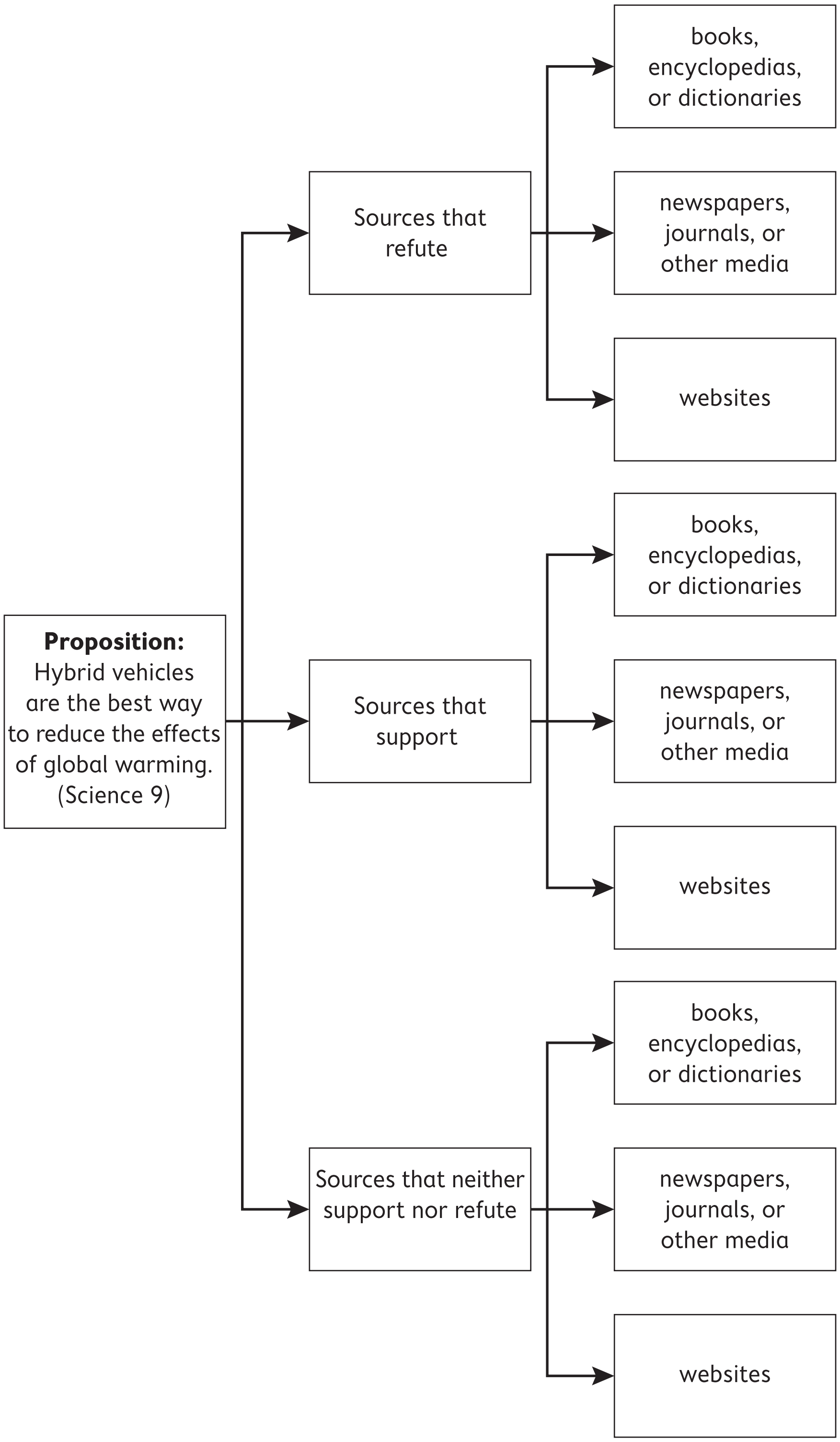
Example 4: Project Summary

Students can use this organizer throughout a project to summarize the project to help focus the relevant content of their study.



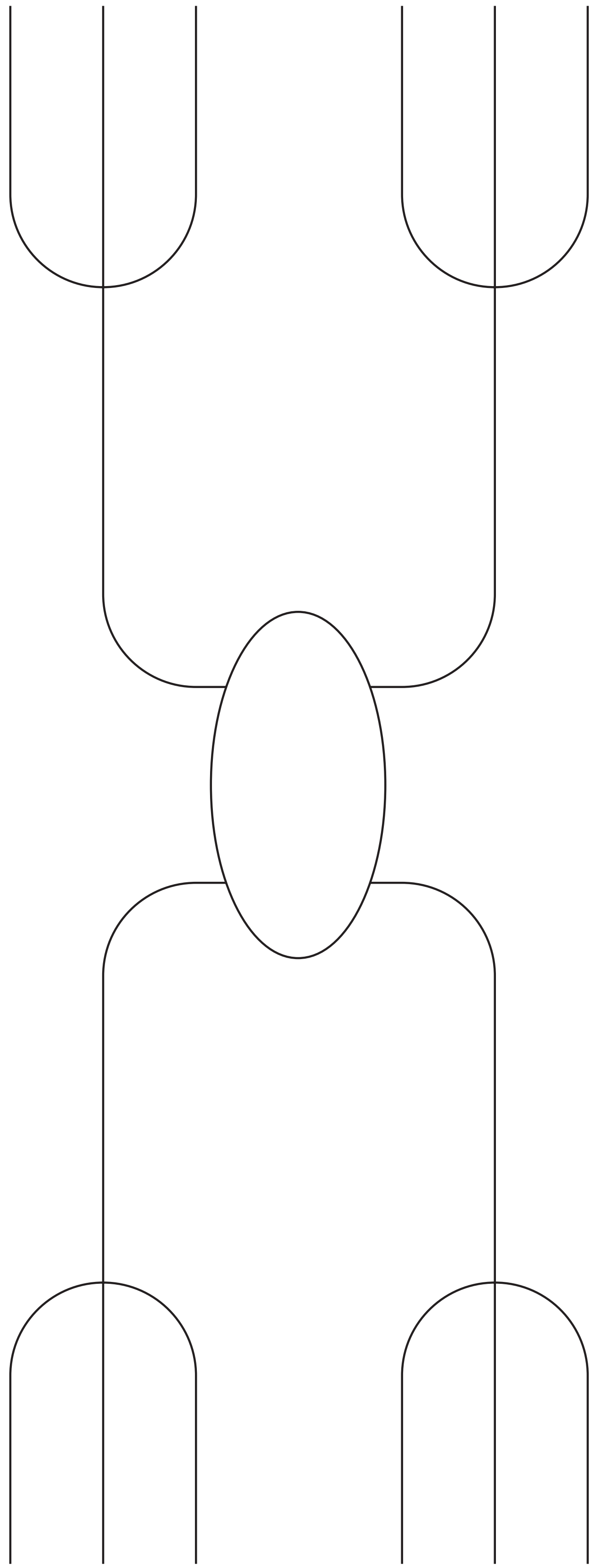
Example 5: Research Organizer

A student can use this organizer to classify the various sources of information that is collected on a topic into more easily researched groupings.

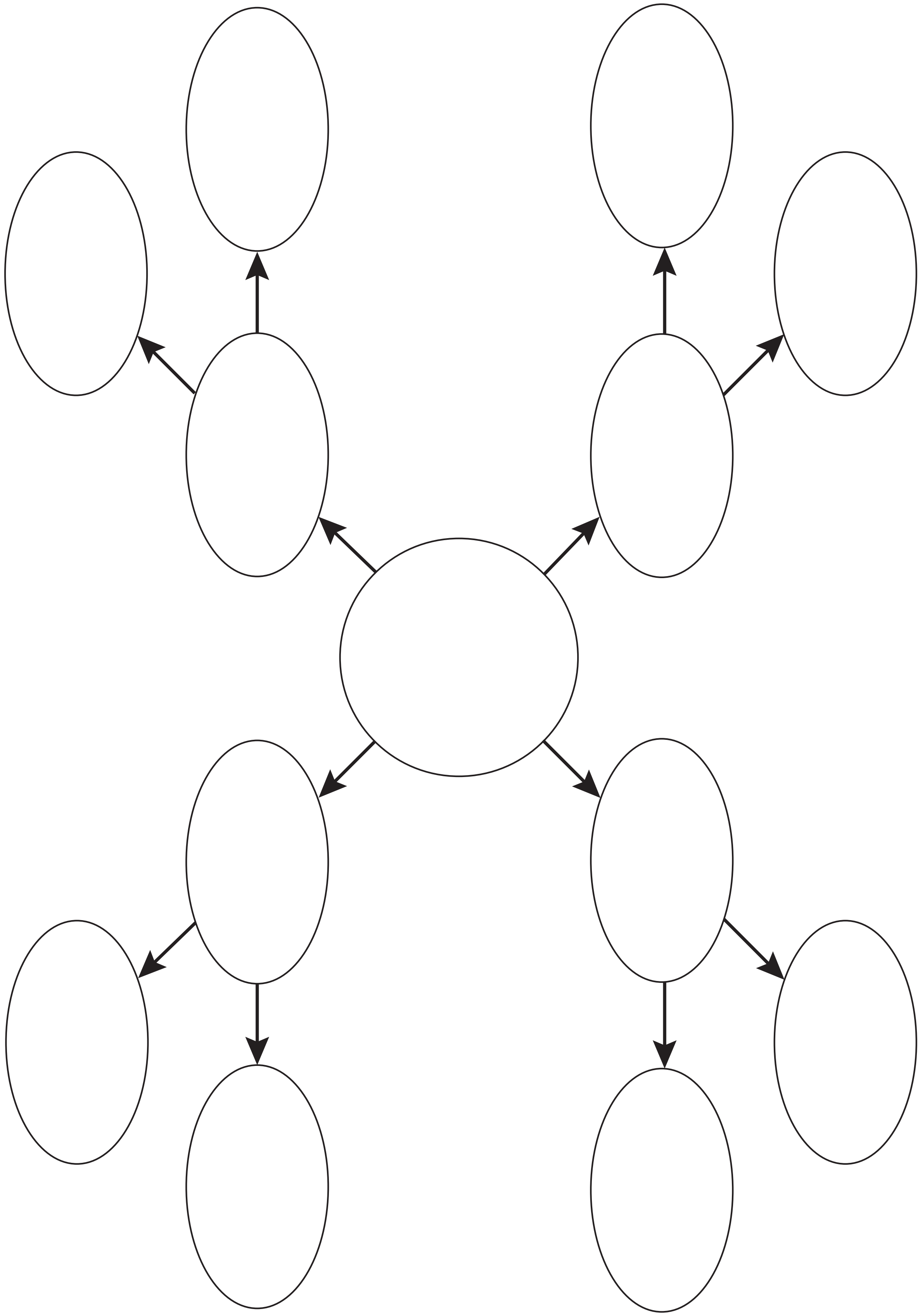


Blank Graphic Organizers

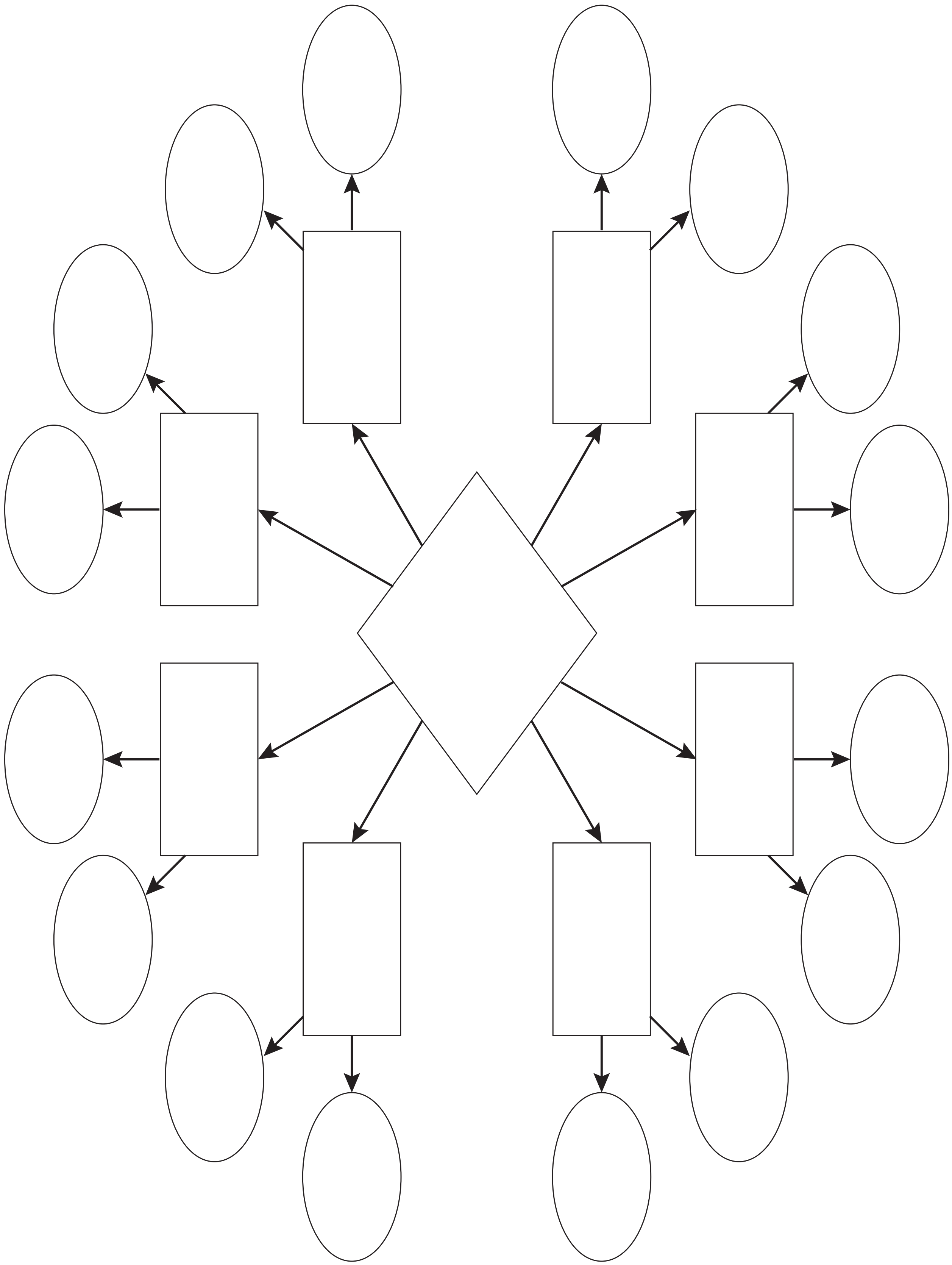
SAMPLE 1: TOPIC ORGANIZER



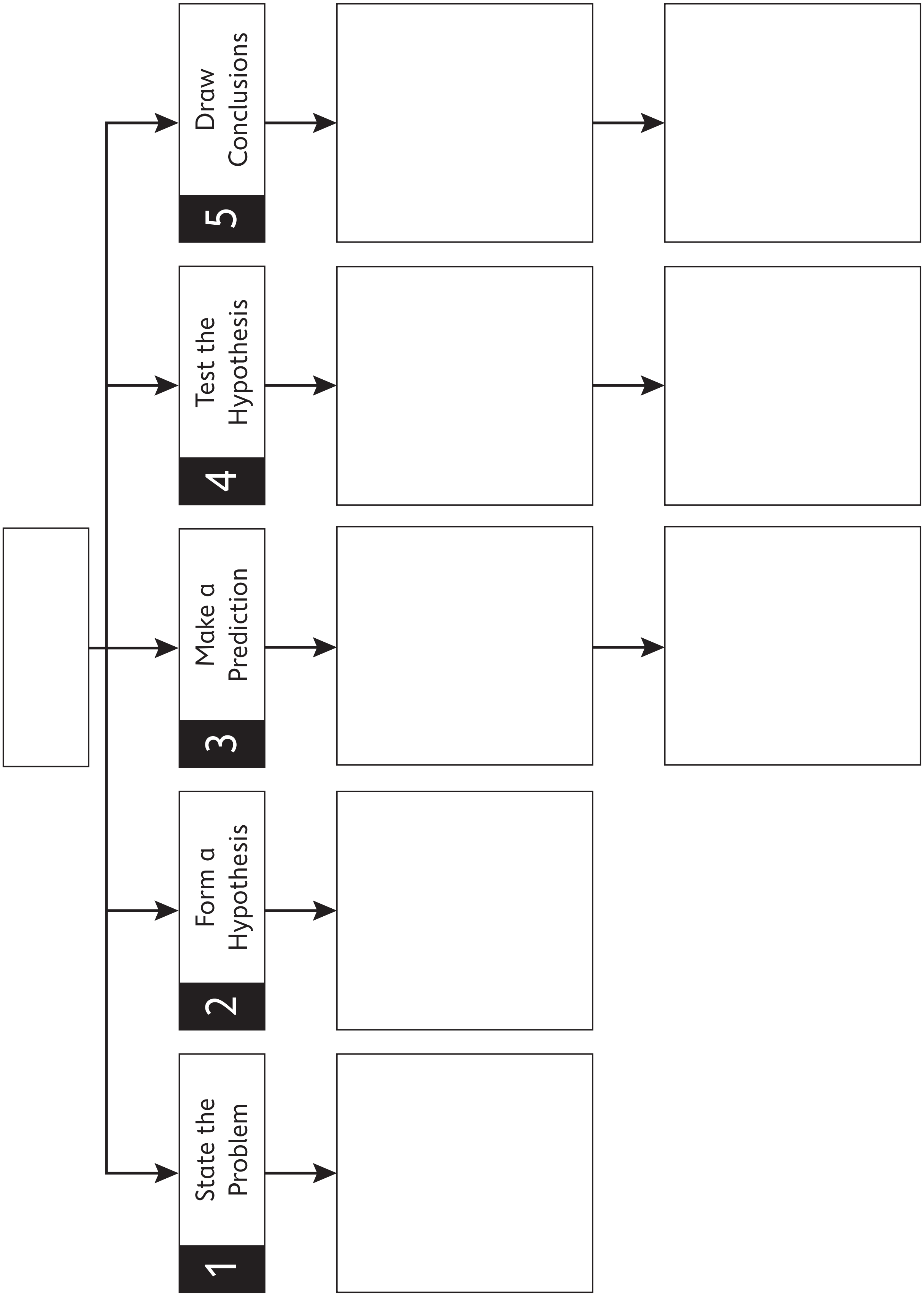
SAMPLE 2: PROJECT ORGANIZER 1



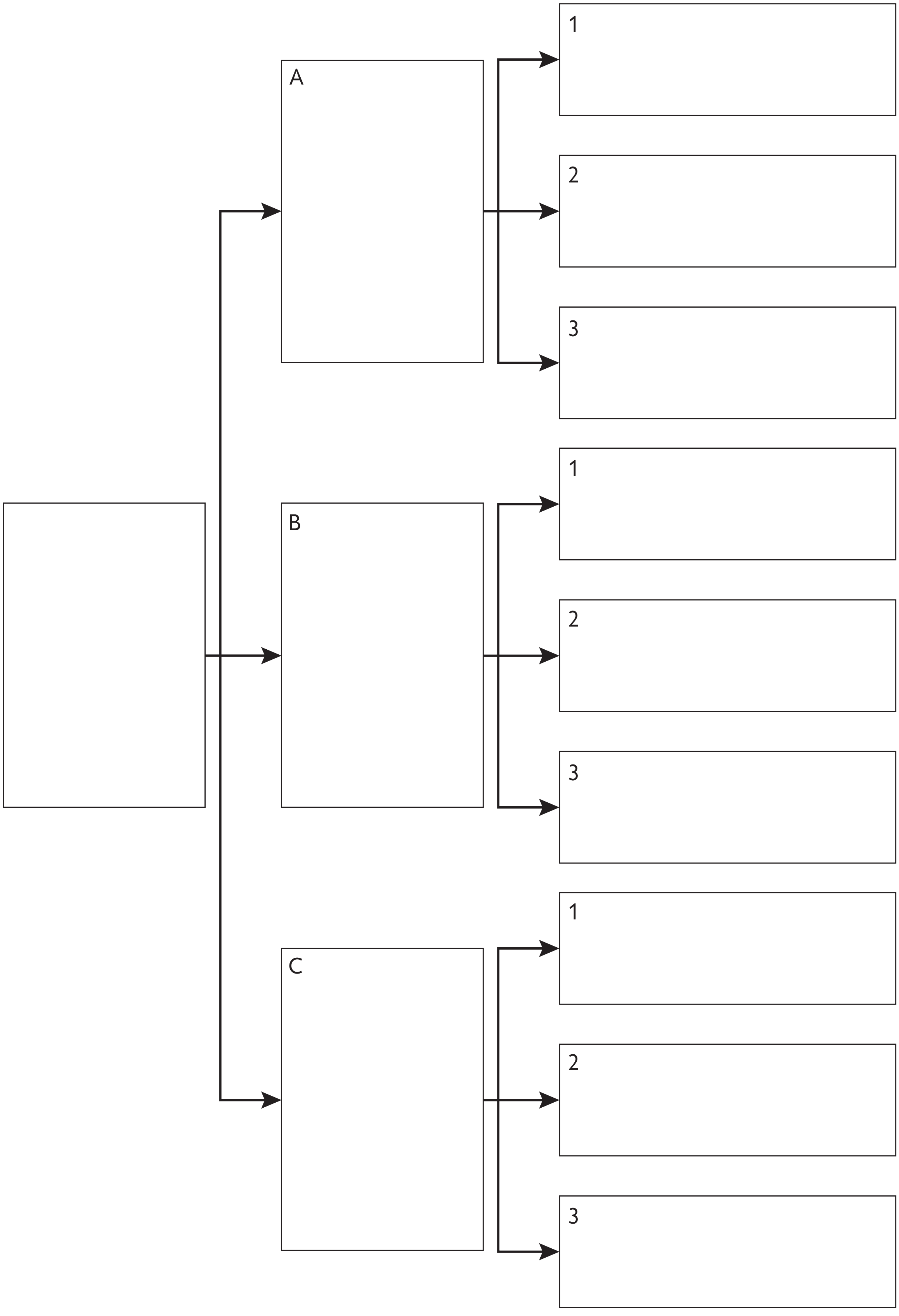
SAMPLE 3: PROJECT ORGANIZER 2



SAMPLE 4: PROJECT SUMMARY



SAMPLE 5: RESEARCH ORGANIZER



Appendix D: Materials Required for Project-Based Science

There is no set list of materials that will assist a teacher in using project-based science in the classroom. The vastness of project types leads to a large variety of required materials. There are, however, a few basic components that should be part of all projects.

1. **Proposed Timelines** (presented at the beginning of the project)
2. **Rubrics or Other Assessment Tools** (developed at the beginning of the project)
3. **Resource Reference List** (a comprehensive list of available resources that should be prepared and obtained before starting a project)
   This list may include
   - magazines
   - newspapers
   - books
   - websites
4. **Inquiry Tools** (experimental activities, software tools, and other activities that should be organized before starting a project)
   These tools may include
   - prepared experimental activities
   - lists of available materials and supplies
   - references to online simulations
   - lists of available modelling software
5. **Project Materials**

The most important issue with materials is to be sure they are arranged before starting a project. Preparing a materials cart or box and bringing it to the classroom or laboratory on each day of the investigation will allow the project to run smoothly and on time.

Appendix E: Science Safety

All projects should be closely monitored to ensure the safety of students and others involved in the research. Teachers must be sure to follow the *Science Safety Guidelines, Grades Primary–12* (Nova Scotia Department of Education 2005) and should be sure that all students, before research begins, know the correct procedures.

Any student research that involves human or animal subjects must be examined closely for the safety of the subjects and the ethics of the research. Any human participant in a research study must have the permission of an adult to participate in the research before it begins.

Any WHMIS information relevant to the topic must be included with the project presentation package and confirmed by the teacher.

Science Safety Guidelines can be downloaded from the Nova Scotia Department of Education website (https://sapps.ednet.ns.ca/Cart/index.php?UID=20120309125330142.227.51.61).

Appendix F: Statistical Analysis for Science Projects

Statistical analysis varies according to grade level. This appendix may be used for Science 7 (Mean, Median, and Mode) and up to grade 12. Students and teachers should decide on the statistical analysis applicable to their project. This appendix includes mathematical concepts. Statistical methods and graphing are an integral part of project-based science activities.

With numbers, we can interpret physical, chemical, and biological concepts. Scientists use numbers to display information that can be interpreted with relative ease.

1. Mean, Median, and Mode

The mean, median, and mode are numbers that provide general information about the typical data for a study. Using statistics, one can interpret how any data collected would fit in with general trends.

Mean: The mean is the average of any set of data calculated by summing all the measurements and dividing the sum by the total number of measurement. The mean is perhaps the most commonly used statistical value. It is useful because it includes all data points and can be used to calculate other statistical values. “Mean” is also commonly known as “average.”

Median: The median is the middle value of any set of data, calculated by arranging the data in ascending order and finding the value that represents the point that 50 percent of the samples are above and 50 percent are below. The median is generally used as a predominant statistic when the results of the study are skewed one way or another, or when a sample is open-ended or incomplete.

Mode: The mode is the most frequently occurring value in a data sample. It is useful in identifying trends and identifying clusters in the data.

Sample High Temperatures for July (°C)

Date	1	2	3	4	5	6	7	8	9	10	11
High temp	20	25	25	24	23	18	22	25	28	28	30
Date	12	13	14	15	16	17	18	19	20	21	
High temp	31	31	28	27	25	22	17	22	25	20	
Date	22	23	24	25	26	27	28	29	30	31	
High temp	21	25	26	24	22	20	22	24	28	26	

Mean: $\mu = \frac{\text{sum of all temps}}{\text{\# days}} = \frac{754}{31} = 24.3\ °\text{C}$

Median: There are 31 data points; thus the middle data point will be the 16th point. As seen below, the 16th data point for our study is 25 °C.

17-18-20-20-20-21-22-22-22-22-22-23-24-24-24-**25**-25-25-25-25-25-26-26-27-28-28-28-28-30-31-31

Note: If there is an even number of data points, the average of the two middle numbers is the median.

Mode: The most frequently occurring high temperature is 25 °C. It occurs six times in the data set.
Note: There may be more than one mode if the data set has two or more values of equal frequency.

WEIGHTED MEAN

If several different data sets with varying numbers of measurements are being examined and the data are combined into one statistical set, the size of these samples must be accounted for. A weighted mean gives more weight over the entire data set to the larger samples.

To calculate the weighted mean, use the following formula:

$$\mu w = \frac{n_1x_1 + n_2x_2 + n_3x_3 + \ldots + n_sx_s}{n_1 + n_2 + n_3 + \ldots + n_s}$$

n = number of data points in an individual set
x = mean of data points in a set
s = number of sample sets

Monthly Daily Mean High Temperatures for June–August

Month	n	x
June	n = 30 days	x = 17.2 °C
July	n = 31 days	x = 24.3 °C
August	n = 31 days	x = 22.8 °C

The weighted mean for the summer would be:

$$\mu w = \frac{(30 \times 17.2) + (31 \times 24.3) + (31 \times 22.8)}{(30 + 31 + 31)} = 21.5\ °\text{C}$$

2. Standard Deviations

Standard deviations are statistics used to measure the variation in a set of data. These can be used to interpret the likelihood of a given result based on how far the value is away from the mean of the total data set. The standard deviation for a given set of data is equal to the square root of the arithmetic mean of the squares of the deviations from the arithmetic mean.

Steps to calculate the standard deviation for temperature data:

1. Subtract each data point from the mean and square the results. (Note: Values that occur more than once in a set of data must be counted for each occurrence.)
17-18-20-20-20-21-22-22-22-22-22-23-24-24-24-**25**-25-25-25-25-25-26-26-27-28-28-28-28-30-31-31
Mean (μ) = 24.3

Standard Deviation

(value – mean)^2	result × number of occurrences	= result
$(17 - 24.3)^2$ =	53.3 × 1 =	53.3
$(18 - 24.3)^2$ =	39.7 × 1 =	39.7
$(20 - 24.3)^2$ =	18.5 × 3 =	55.5
$(21 - 24.3)^2$ =	10.9 × 1 =	10.9
$(22 - 24.3)^2$ =	5.3 × 5 =	26.5
$(23 - 24.3)^2$ =	1.7 × 1 =	1.7
$(24 - 24.3)^2$ =	0.1 × 3 =	0.3
$(25 - 24.3)^2$ =	0.5 × 6 =	3.0
$(26 - 24.3)^2$ =	2.9 × 2 =	5.8
$(27 - 24.3)^2$ =	7.3 × 1 =	7.3
$(28 - 24.3)^2$ =	13.7 × 4 =	54.8
$(30 - 24.3)^2$ =	32.5 × 1 =	32.5
$(31 - 24.3)^2$ =	44.9 × 2 =	89.8

2. Add the results of the last column and divide by the number of total data points.

$$\frac{\text{sum of results}}{\text{\# data points}} = \frac{381.1}{31} = 12.3$$

3. Take the square root of your result in step two to obtain the standard deviation for your data set.

$\sigma = \sqrt{12.3} = 3.5$

The mathematical equation to describe the operation performed is:

$$\sigma^2 = \frac{\sum(x-\mu)^2}{n}$$

where μ is the mean, n is the number of samples, and x is a given data point.

USING A PORTION OF THE DATA

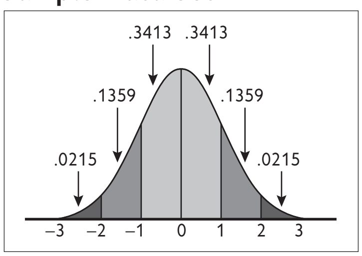
If only a portion of the data is analyzed, the calculation of the standard deviation is slightly different. It becomes somewhat larger to represent the fact that there would likely be more variation if the entire population were used in the calculation. The calculation is calculated using

$$s_x^2 = \frac{\sum(x-\mu)^2}{n-1}$$

For the temperature data, the sample mean would be 3.6.

To analyze a normally distributed data set, a normal curve is plotted. The mean corresponds to the peak of the curve. Units of one standard deviation are drawn to the left and right of the mean, as shown in the chart. The total volume of the space between the curve and the x-axis represents 100 % of the data points.

Sample Data Set



This curve shows that for a normally distributed set of data, 34.1 % of the measurements should be within one standard deviation greater than (right of) the mean and 34.1 % within one standard deviation less than (left of) the mean. Therefore, for our temperature example, with a mean of 24.3 °C, 68.2 % of our data (1 from the mean) should lie between 20.8 °C and 27.8 °C. Likewise, 95.4 % of our data (2 from the mean) should lie between 17.3 °C and 31.3 °C. If the data do not fall into these ranges, it would suggest that there is something unusual about our sample, or that our sample is too small.

The actual ranges for our data are 19/31 (61.3 %) within one standard deviation and 30/31 (96.8 %) within two standard deviations. Our data are basically normally distributed.

3. Best-Fit Analysis: Line of Best Fit

One of the most common methods of data analysis is “line of best fit.” This is sometimes called median-median (med-med) plotting. When data are plotted on a (x, y) coordinate system, a linear pattern often arises as a way to describe the relationship between two variables in an experiment or study.

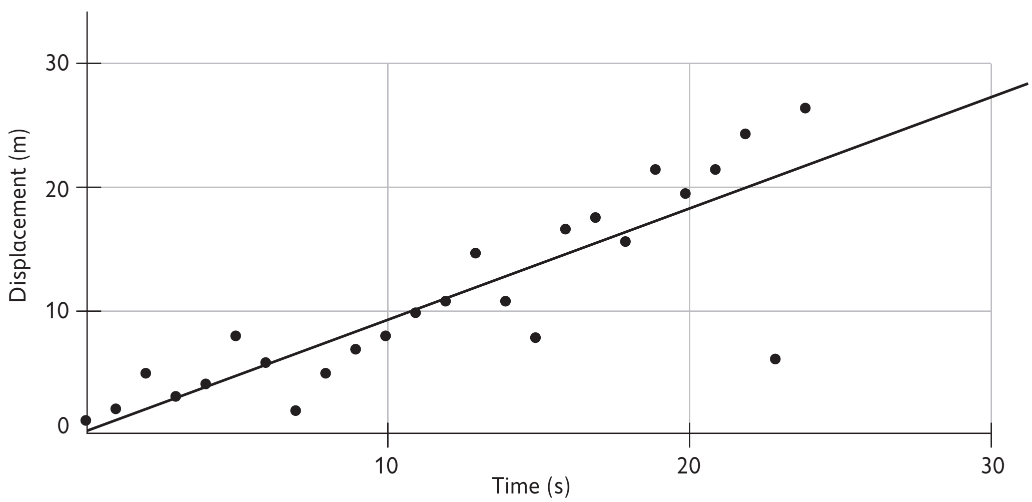
Example: The following data set represents the displacement of an object that has travelled from its start position over time. The x-axis is the time in seconds, and the y-axis is the displacement in metres.

Displacement vs. Time Data

times (s)	0	1	2	3	4	5	6	7	8	9	10	11	12
displacement (m)	1	2	5	3	4	8	6	2	5	7	8	10	11
times (s)	13	14	15	16	17	18	19	20	21	22	23	24	
displacement (m)	15	11	8	17	18	16	22	20	22	25	6	27	

The line of best fit for these data can be described by the equation $d(t) = 0.89t + 0.49$. From this we can assume that the velocity of the object is approximately 0.89 m/s.

Displacement vs. Time Graph



A visual examination of the graph shows that there are a large number of data points that stray far from the plotted line. These points, or outliers, can skew the results of the line of best fit and introduce error into the analysis. To remove the possibility of this error, a med-med plot can be used.

To create a med-med plot, the data must first be sorted into three groups. Those in the bottom third of *x*-values, those in the middle third of *x*-values, and those in the top third of *x*-values. The sets are then arranged so both the *x*- and *y*-values are in ascending order. The medians of these points are then used to set up the linear plot. The medians of the low set and the high set are plotted on a graph, and the equation of the line connecting them is determined. The slope of this line is the slope of the med-med line. The *y*-intercept is determined using the middle-third point. The entire line is shifted one third of the distance toward the line, and the line of the med-med plot is determined. This new line greatly reduces the value of outliers in a plot.

Bottom 1/3	0	1	2	3	4	5	6	7
Not sorted	1	2	5	3	4	8	6	2

Bottom 1/3	0	1	2	**3**	**4**	5	6	7
Sorted	1	2	2	**3**	**4**	5	6	8

Middle 1/3	8	9	10	11	12	13	14	15	16
Not sorted	5	7	8	10	11	15	11	8	17

Middle 1/3	8	9	10	11	**12**	13	14	15	16
Sorted	5	7	8	8	**10**	11	11	15	17

Top 1/3	17	18	19	20	21	22	23	24
Not sorted	18	16	22	20	22	25	6	27

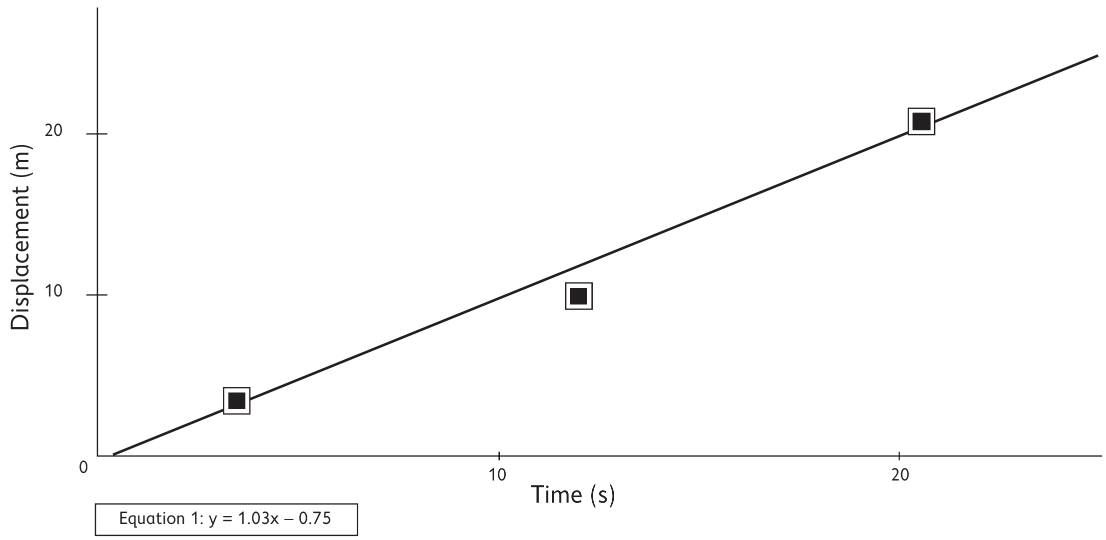
Top 1/3	17	18	19	**20**	**21**	22	23	24
Sorted	6	16	18	**20**	**22**	22	25	27

The median of the bottom third is (3.5, 3.5), the median of the middle third is (12.0, 10.0), and the median of the top third is (20.5, 21.0). Using the high and low points, we get the equation d(t) = 1.03t – 0.11, where d is displacement and t is time.
Substitute t = 12.0 (t-coordinate of the middle median): d = (1.03 × 12.0) – 0.11 = 12.25
Subtract 12.25 from 10.0 (d-coordinate of the middle median): 10.0 – 12.25 = –2.25
Divide the result by 3 to get the d-intercept for the med-med line: –2.25/3 = –0.75
Thus, the equation for the med-med line is d(t) = 1.03t – 0.75.

This line gives a better representation of the trend in position-time data, minimizing the effect of variations in data sets.

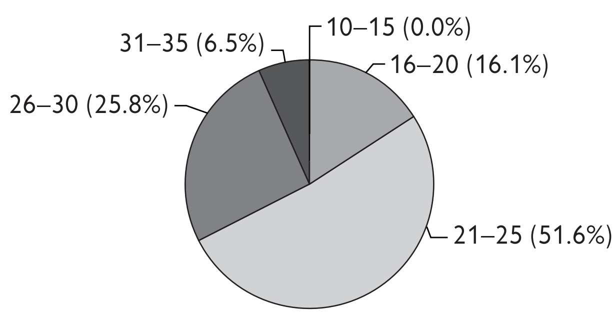
4. Displaying Data

Graphical displays of data allow a study to be quickly analyzed and examined for trends.



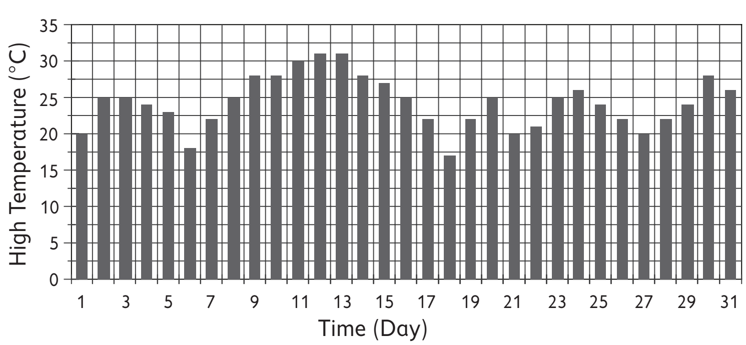
A. Pie charts show the percentage distribution of data based on defined ranges.

July High Temperatures
(Temperatures are in degrees Celsius.)

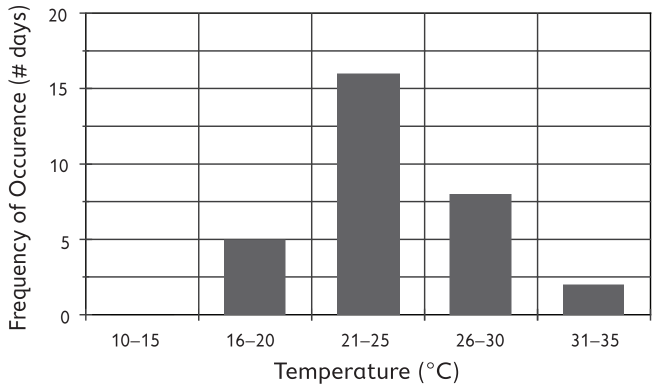


B. Bar graphs show data trends in a number of defined settings; for example, daily temperatures or specific temperature ranges.

July High Temperatures
(Temperatures are in degrees Celsius.)



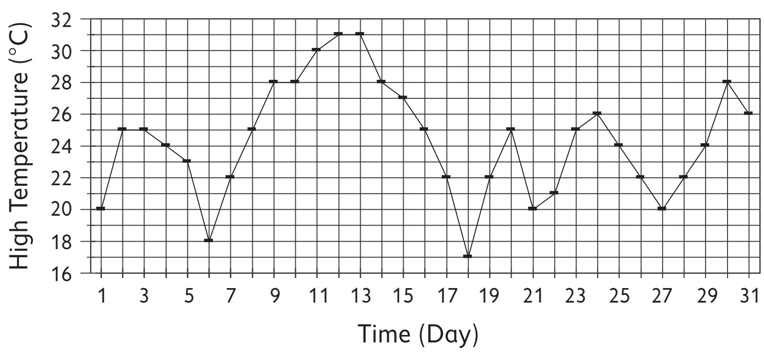
July High Temperatures
(Temperatures are in degrees Celsius.)



C. Line graphs are similar to bar graphs and easily describe the changes in data points.

July High Temperatures

(Temperatures are in degrees Celsius.)



5. Other Mathematical Tools

The *McGraw-Hill Ryerson Physics* textbook contains an appendix describing, with examples, some mathematical skills that are often used in physics. These skills include percent differences, significant differences, drawing graphs, and calculating areas and volumes.

The Descriptive Statistics Unit in the Mathematics 11 *Mathematical Modeling Book 2* (Barry 2004) provides an in-depth exploration of using statistics to display information.

To assist students with much of the data analysis described above, technologies such as graphing calculators and scientific probes can be used.

Appendix G: The Energy Around Us, Renewable Energy in Nova Scotia (Grade 9 Pilot Project)

The overarching theme for this project-based learning pilot was energy and sustainability. In March of 2010, the Nova Scotia Department of Education and the Nova Scotia Department of Energy embarked upon a joint endeavour to engage students in project-based learning focusing on the topic of renewable energy. Working with teachers from across the province, the department held workshops and provided resources and support to teachers and students. The project involved a multidisciplinary approach including subject areas such as science, social studies, mathematics, English language arts, and arts education.

Over a ten-week period, students were encouraged to take part in project-based learning that focused on student-directed questions and research initiatives on the subject of renewable energy resources available in Nova Scotia—wind, biomass, hydro, tidal, geothermal, and solar. Some of the research looked at renewable energy resources in the province and implications for the future while others looked at why renewable energy resources should be valued. Students were encouraged to make connections to their community through investigating the careers associated with their research focus and to identify what actions they could undertake to educate and encourage the support and use of renewable energy resources.

A student celebration was held in June 2010 in Halifax for all of the students across the province who participated in this project-based learning endeavour.

Appendix H: Project-Based Investigations

Investigations vary. An experiment is an investigation, but not all investigations are experiments. Below are three examples of project-based investigations.

EXPERIMENT

Experiments test specific questions. Recognition of variables and controls for the experiment must be determined. Demonstration of the collection, analysis, and presentation of data are included in an experiment. It is not essential that any significant positive findings result from the experiment. It must be recognized that it is the design, rather than the results, that is most important.

STUDY

This type of project involves the collection and analysis of data from various sources to reveal evidence of a fact, situation, or pattern of scientific interest. This could include a study of cause-and-effect relationships or theoretical investigations of scientific data. This should demonstrate that the methods used to obtain the original data involved sound scientific techniques and controls and demonstrate insightful analysis.

INNOVATION

An innovation involves the development and evaluation of new devices, models, techniques, or approaches in fields such as engineering or technology. This should integrate several technologies, inventions, and/or designs, and construct an original innovative product that will have commercial application and/or human benefit. This type of project must demonstrate how the innovation was designed and/or developed on the basis of a sound understanding of the scientific principles involved.

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