SCI-TECH ONTARIO

REAL SCIENCE:

USING PROJECTS TO ENGAGE STUDENTS AND MEET THE GOALS OF THE ONTARIO CURRICULUM

Grade 7/8

(First Edition)

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Section One: Benefits of Project-Based Science and Technology

Introduction:

This document is aimed at teachers, parents, and administrators who would like to involve students in project-based science and technology. Project-based science is an effective tool for the development of critical thinking skills, and for achieving expectations of the Ontario curriculum. It allows young people to be involved in authentic scientific inquiries, which will increase their understanding of how science works in the real world. This, in turn, helps develop citizens who are scientifically literate and able to look at current and future scientific and technological issues with a critical and understanding eye.

This document is divided into two sections. The first looks at the benefits of doing project-based science. The second looks at ideas and strategies for incorporating project-based science and technology in classroom and school programs.

What is Project-Based Science and Technology?

"Creativity in scientific research is seeing what others have not seen, and making it visible to others."

Dr. Tom Brzustowski, President, Natural Sciences and Engineering Research Council of Canada

Sachi and Amy are conducting an independent science project at the end of the optics unit in grade 8. One of their guided inquiries during the unit looked at the refraction of light. The girls saw that a glass of water was able to refract light and they wondered if the shape of the water had an effect on refraction. In their project, they took a volume of water, poured it into containers of different shapes, and looked at the refraction of light. Their teacher asked them if they could think of a way to measure the amount of refraction for each container. The girls discussed how they could measure the angle of refraction or angle of incidence, two concepts they had learned about in class…

Students who are allowed to pursue genuine science questions, or solve genuine technological problems, are engaged in project-based science. Students actively construct meaning and are engaged in authentic learning when they are investigating questions that are real. These questions may arise in science class, in other subject areas, or from activities and interests that students have outside of school.

Projects are a natural culminating event in a unit of a well-rounded science and technology program. A well-rounded program includes readings, demonstrations, debates, videos, and "lab" work that is purposeful. Purposeful inquiries or labs get students thinking critically about the big concepts and questions in a unit of study. They develop inquiry and design skills, and allow discussion of the key concepts in small and large groups. It is vital that these activities engage students in constructing meaning and understanding; "hands-on" activities are not effective if they are not "minds-on" as well.

Start small: Although projects are usually presented as an extended investigation, there is considerable value, particularly in the early stages of developing inquiry and design skills, for shorter-term 'projects' or challenges. Science Olympics events and technology challenges are good examples of engaging short-term projects. The key to meaningful learning with short-term activities is effective follow-up and the opportunity to integrate new understanding and experience. Building a straw tower once is simply a challenge. Building a second tower – after discussing the effectiveness of designs with

peers and exploring the strength and stability of various geometric shapes – makes the activity a meaningful sci-tech learning experience.

Project-based Science and Technology And The Curriculum

The science and technology curriculum is intimidating because of the number of expectations that appear in the curriculum document. Teachers may shun science and technology projects because of time pressures and the perceived need to "cover" the curriculum. A close look at the curriculum, however, shows that independent inquiries and projects address important goals of science and technology education— goals that are difficult to address in other ways — and still allow enough time to teach the entire curriculum.

Goals of grade 1-8 Science & Technology Education

"Students must develop a thorough knowledge of basic concepts which they can apply in a wide range of situations. They must also develop the broad-based skills that are so important for effective functioning in the world of work: they must learn to identify and analyze problems and to explore and test solutions…" Ontario Curriculum Grades 1-8, Science and Technology, p. 3.

"Every great advance in science has issued from a new audacity of imagination."

John Dewey, The Quest for Certainty

In order to incorporate project-based science in the curriculum, it is important to understand the extent to which this approach will meet the goals and aims of science and technology education. The Ontario curriculum for elementary science and technology is organized around specific content areas or units of study. As a result, planning for these units often focuses on content and ways in which students can learn the "facts" about a certain topic. This approach to planning, especially for elementary teachers (many of whom do not have a science background), makes it tempting to rely on textbooks, worksheets, simple demonstrations, and relatively unengaging hands-on activities to cover a unit. Although textbooks can be an important part of a science unit and are useful for introducing basic scientific concepts, reliance on textbooks and worksheets may give teachers, administrators and parents the impression that the curriculum has been taught, when in fact it hasn't. Covering content achieves only the first of the three basic goals of elementary science and technology education:

"i) understanding of the basic concepts of science
ii) development of the skills, strategies, and habits of mind required for scientific inquiry
iii) relating scientific and technological knowledge to each other and to the world outside the school

These goals are equally important. They can be achieved simultaneously through learning activities that combine the acquisition of knowledge with both inquiry and design processes in a concrete, practical context." (The Ontario Curriculum, Grades 1-8: Science and Technology, p. 4)

A classroom program with an overemphasis on content tends to dwell on vocabulary and note-taking to convey large amounts of information in the false belief that by being able to recall this information, the students "know" science. A classroom program that incorporates project-based science is more likely to ensure that an appropriate balance of concepts, skills, and attitudes are learned. Students who *really* know science are those who are able to successfully complete an independent inquiry or design project that addresses a question or problem that is relevant to them.

Overall Expectations versus Specific Expectations

Each unit of the grade 1-8 science and technology curriculum has three overall expectations, which correspond to the three overall goals of the science and technology curriculum (see page 2). The overall expectations are what teachers are responsible for, and the specific expectations are listed as suggestions to help achieve the overall expectations. When looked at in this way, the curriculum becomes more manageable.

Projects are a viable way to cover the three overall expectations in a unit. Inquiry and design skills are inherent in a project, and project topics chosen from a specific unit of study can cover content from the unit, as well as relating science and technology to the world.

An example of a project that covers the 3 Overall Expectations of a unit

Thomas Pocock and Adam Martin, two grade 8 students from Peel, went to the Canada Wide Science Fair with a project entitled "Friction: Quick Minds Make Fast Cars": "We sought to determine which of oil, grease or water "best" lubricated two identical steel surfaces. To arrive at and explain our conclusions, we calculated "coefficients of friction", determined "mean", and compared "standard deviations" (taken from their 50 word abstract)

"The great tragedy of science -- the slaying of a beautiful hypothesis by an ugly fact."

Thomas Huxley

Thomas and Adam discussed and applied concepts related to properties of fluids and friction in their project. They used inquiry and design skills to conduct their experiment, and statistical methods to analyze their results. They also looked at the practical implications of using the various fluids in real-world situations.

Authentic Learning and Assessment

The above example shows how real questions or technological problems offer authentic learning opportunities for students, and authentic assessment opportunities for teachers. This type of work is more motivating and interesting for students than memorizing and regurgitating facts on a test, and tends to produce a better effort.

Projects are an effective summative assessment of the overall expectations, and allow the student to demonstrate knowledge of concepts, inquiry and design skills, and the ability to relate science and technology to his/her world.

A Project as a Culminating Activity

Some teachers hesitate to incorporate projects in their program because they want students working within a certain unit of study or curriculum strand. The solution? In grade 7 and 8, a science and technology project can be an excellent culminating activity for a unit. Throughout a unit of study, the new knowledge and skills that students develop should lead to further questions. At the end of the unit, relevant or important questions can be investigated as a culminating activity that requires the students to use their skills of inquiry and design to answer a question or solve a problem directly related to the unit.

In technological strands, such as "Structures and Mechanisms," the culminating activity could be a technology challenge, where students use their skills and knowledge to solve a specific problem. As in the real world, the challenge can be very specific, but should give enough flexibility for students to develop creative and innovative solutions. Using an independent project or inquiry as a culminating activity provides students with open-ended opportunities to demonstrate their scientific and technological skills and understanding. Quizzes, tests, or writing assignments during the unit can be used to check basic understanding of the key concepts, while the culminating activity assesses a deeper understanding of the concepts and an appreciation for applications in the real world. In addition, some students can work independently, allowing teachers to focus attention on those students requiring assistance in developing or applying the skills and strategies needed to successfully complete an independent inquiry.

Recurring Inquiry and Design Expectations

For grade 7 and 8, there are five inquiry and design expectations that run through all strands and units of the science and technology curriculum. These five expectations represent essential skills that students must demonstrate to show that they have mastered the curriculum. They are also essential skills that students need in order to successfully complete an independent project. Projects, then, are an effective and authentic way to assess inquiry and design skills, as well as content of a unit (see the section **"A project as a culminating activity"** for more details).

Grade 7 & 8: Five Inquiry and Design Expectations Found in All Strands

- formulate questions about and identify needs and problems related to…(ending depends on the specific strand content)
- plan investigations for some of these answers and solutions, identifying variables that need to be held constant to ensure a fair test and identifying criteria for assessing solutions
- use appropriate vocabulary, including correct science and technology terminology, to communicate ideas, procedures, and results
- compile qualitative and quantitative data gathered through investigation in order to record and present results, using diagrams, flow charts, frequency tables, bar graphs, line graphs, and stem-and-leaf plots produced by hand or with a computer
- communicate the procedures and results of investigations for specific purposes and to specific audiences, using media works, oral presentations, written notes and descriptions, charts, graphs, and drawings

Enduring Understanding and Scientific Literacy

Project-based science and technology encourages students to reawaken their curiosity and ability to explain the world around them. Sadly, by the time many young people reach grade 7 and 8, they have suppressed these natural abilities, having received a clear message from school that knowledge of facts is more important than inquiry, experimentation and design. By being encouraged to investigate questions that are genuine and interesting, students can be actively engaged and gain a more realistic and enduring understanding of the processes involved in scientific inquiry. Understanding how science works in the real world is an important step toward scientific literacy. Although many students will not end up in careers directly related to science and technology, an understanding of the processes involved will allow them to follow emerging controversies, think critically about issues, and form reasoned opinions about them. Critical thinking skills developed through science inquiries and projects carry over to all curriculum areas and facets of life.

Actively working as young scientists allows students to develop the key concepts, or enduring understandings, that are essential for understanding a topic in science and technology (Wiggins and McTighe, Understanding by Design, page 11). Through project-based science, students can undertake independent investigations that take a meaningful, in-depth look at topics related to the key concepts in a unit, giving them time to ponder, debate and understand the essential ideas. A hands-on (and minds-on) approach provides a rewarding and engaging experience for students, increasing their enjoyment of science and technology, and increasing the likelihood of them continuing to take courses in science and/or technology in high school.

"Uncoverage" of Enduring Understanding and Constructivist Learning

"All modern subject areas are grounded in nonobvious ideas: The Earth does not appear to move; there are no obvious signs of our being descended from primates…" (Wiggins and McTighe, p. 112-113)

From the point of view of students, many of the key concepts that form the backbone of the grade 1-8 science and technology curriculum are not obvious. Grade 7 students are told that all matter is in motion, but when they take a good look at their desk, it doesn't seem to be moving! Some of the "big ideas" that are crucial for understanding of a topic need to be investigated and discussed by students in order for them to construct a thorough and meaningful understanding.

Coverage of every Ontario Curriculum expectation in equal detail (or working through a textbook from cover to cover) to "teach" the curriculum is problematic because students often are unable to distinguish the key ideas, or do not develop a deep understanding of them. A grade 7 student may memorize and recite the postulates of the kinetic molecular theory, but will usually resort to his or her own understanding of heat to explain and understand everyday events. Children are active theory makers from the time they are very young, and come to grade 7 and 8 with many well formed (though often unscientific) conceptions of how the world works. These understandings are rarely acknowledged or explored in most classrooms, but research has shown that these "alternative conceptions" serve the student well and are remarkably resistant to instruction. Inquiry and design activities, and projects specifically, encourage the student to put his/her conceptions to the scientific test, setting the stage for him/her to construct a new and more scientific understanding.

"The teacher taught it, but that doesn't mean I learned it" applies all too often to science and technology. A classroom atmosphere that challenges students to think and talk about the big concepts increases understanding. The science and technology teacher's role is to help the student integrate the everyday process of making meaning with the strategies of scientific thinking, logic, and knowledge of scientific principles. Projects can provide an opportunity for students to look at questions or problems surrounding some of the key concepts in grade 7/8 science and technology, and develop principled learning about them.

The Role of Dialogue in Inquiry and Design

Inquiry and design are dynamic, interactive and social processes. A teacher who does

most of the talking in a sci-tech classroom may broadcast a lot of information and believe that the curriculum is being 'covered,' but he/she is unlikely to help students develop meaningful understanding. Cooperative learning strategies and working in pairs or small groups are more effective approaches to learning in science and technology, and for working on projects. When students are encouraged to discuss observations and ideas with a partner or small group, they can engage in informal hypothesizing, theory making, and explaining – vital activities in the construction of new understandings and the development of inquiry and design skills. However, discussions only work if there's something worth discussing! Facilitating meaningful discussion requires that students be engaged in exploring interesting phenomena in an environment that encourages them to try different approaches and make a variety of 'discoveries.' The sharing of pair or small-group discoveries guided by questioning and input from the teacher, can lead to lively class discussions that deepen understanding. This type of environment is most supportive for project-based science and technology.

Curriculum Integration

Christine, a grade 7 student, has been spending the past week in her language class practicing procedural writing. In mathematics class, she looks at different methods of displaying data and what types of data are suitable for each of the methods. In science, she uses what she has learned in language and math to help her complete her science project, entitled "Which all-natural solution is best at removing stains?" During the school's science celebration, her language teacher assesses how well she has used procedural writing, followed by her math teacher, who assesses her data management.

Project based science and technology in grades 7 and 8 provide a rich opportunity for the integration and assessment of multiple curriculum strands. Successful integration often requires collaboration among teaching colleagues, as most students at the grade 7/8 level have more than one teacher for subjects such as mathematics, science, and language. Science and technology projects provide an excellent opportunity for teachers to collaborate and participate in shared planning. Learning in several subjects becomes more meaningful, because students know the skills and knowledge will be needed to successfully complete their projects. Projects can also provide an opportunity for extended, uninterrupted learning, where time in several subject areas is combined to complete their projects.

Language

"Activities that students see as meaningful and that challenge them to think creatively about topics and concerns of interest to them will lead to a fuller and more lasting mastery of the basic skills. Equally important, writing activities in which students are involved as creative learners and thinkers will demonstrate to them that clear writing is the result of clear thinking and the disciplined application of the conventions of writing." (Ontario Curriculum, Grades 1-8, Language, page 10).

To successfully complete an independent science and technology investigation, students must be able to incorporate many of the overall expectations outlined in the grade 7 and 8 writing program. In addition to written language, oral language skills can be assessed during the judging process, or during oral reports given to the class.

Grade 7 Overall Language Expectations that can be assessed as part of science and technology projects:

- communicate ideas and information for a variety of purposes (to outline an argument, to report on observations) and to specific audiences, using forms appropriate for their purpose and topic (e.g., write a lab report for an audience familiar with the scientific terminology);
- use writing for various purposes and in a range of contexts, including school work (e.g., to make point-form notes from a text, to jot down personal impressions);
- organize information to develop a central idea, using well-linked and well-developed paragraphs;
- use a variety of sentence types and sentence structures, and sentences of varying length;
- produce pieces of writing using a variety of forms (e.g., descriptive, narrative, and expository compositions), techniques and resources appropriate to the form and purpose, and materials from other media (e.g., diagrams, illustrations);
- produce media texts using writing and materials from other media (e.g., a poster inviting members of the community to a school play; a multi-media presentation on an assigned topic);
- revise and edit their work, focusing on content and elements of style (e.g., diction), independently and in collaboration with others;
- proofread and correct their final drafts, focusing on grammar, punctuation, spelling, and conventions of style;
- use and spell correctly the vocabulary appropriate for this grade level;
- use correctly the conventions (spelling, grammar, punctuation, etc.) specified for this grade level (see below).

"Facts are the world's data. Theories are structures of ideas that explain and interpret facts."

Stephen Jay Gould "Evolution as Fact and Theory", in Hen's Teeth and Horse's Toes, W.W. Norton, 1984.

Grade 8 Overall Language Expectations that can be assessed as part of science and technology projects

- communicate ideas and information for a variety of purposes (to evaluate information, to compare points of view) and to specific audiences, using forms appropriate for their purpose (e.g., a survey soliciting opinions on an environmental issue) and features appropriate to the form (e.g., focused questions);
- use writing for various purposes and in a range of contexts, including school work (e.g., to write technical instructions, to clarify personal concerns, to explore social issues, to develop imaginative abilities);
- organize information and ideas creatively as well as logically, using paragraph structures appropriate for their purpose (e.g., paragraphs structured to develop a comparison or establish a cause-and-effect relationship);
- use a wide variety of sentence types and sentence structures, with conscious attention to style;
- produce pieces of writing using a variety of specific forms (e.g., a script for a play), techniques and resources appropriate to the form and purpose, and materials from other media (e.g., lighting effects);
- produce media texts using writing and materials from other media (e.g., a video documentary on an environmental issue);
- revise and edit their work, focusing on content and on more complex elements of style (e.g., imagery), independently or using feedback from others;
- proofread and correct their final drafts, focusing on grammar, spelling, punctuation, and conventions of style;

- use and spell correctly the vocabulary appropriate for this grade level;
- use correctly the conventions (grammar, spelling, punctuation, etc.) specified for this grade level

Mathematics

Mathematics is another subject that can easily be integrated with, and assessed through, science and technology projects. There are many topics in math that might apply in a project, but data management and probability will be found in most projects involving experiments or correlational studies. For students looking for enrichment in mathematics, science and technology projects are also an excellent way to get students looking at basic concepts in statistics, such as standard deviation and standard error.

"Mathematics is the chief language of science. The symbolic language of mathematics has turned out to be extremely valuable for expressing scientific ideas unambiguously."

American Association for the Advancement of Science. Science for all Americans.

Visual Arts

When presenting their project, students can use principles of design from the visual arts curriculum to make their project display more organized and appealing. Examples include having a strong focal point on their display board, and using symmetry to give their displayed work a balanced feel.

Co-Curricular Projects

Science and technology projects as part of a Science Club make an excellent co-curricular activity. Because it is a voluntary activity, students are usually highly motivated, and are free to work on topics that are of personal interest. The teacher acts as an advisor or facilitator, giving students guidance as they need it and making suggestions when appropriate.

Section Two: Developing a Science and Technology Program that Incorporates "Real Science" and Projects

Before "unleashing" students to conduct independent science and technology projects, they need to be well prepared. This does not need to take a long time. A science and technology program that effectively addresses all three overall goals will give students the skills, knowledge, and attitudes needed to successfully complete projects.

Fostering an Authentic View of Science & Technology

"There are many hypotheses in science which are wrong. That's perfectly all right; they're the aperture to finding out what's right." Carl Sagan

Many science programs that are heavy on content do not foster an authentic view of how science works. There are several key misconceptions held by teachers, students and the public that can interfere with the success of students doing their own projects:

"The important thing is not to stop questioning."
Albert Einstein

- **Misconception 1: There is only one "right" answer.** Many science "experiments" in textbooks or on worksheets are no more than cookbook-like recipes, where all students follow the same procedure, and are intended to get the same result. Those students who get a different answer are "wrong." While this type of activity – they are not experiments – can be useful to demonstrate a specific scientific principle, it offers little room for actual inquiry, and often generates little or no discussion. This approach fosters a view that science is a very "clean" discipline, where everyone agrees on the facts and their interpretation. Nothing could be further from the truth! The history of science is filled with vigorous and vitriolic debates as new discoveries overturned long-held views and new theories emerged. Answers in science are always tentative and are certainly debatable as data can often be interpreted in different ways. With a classroom approach that acknowledges scientific controversies, teachers can ignite critical thinking in students and help them to understand that the "conclusions" of one experiment might last only as long as the next experiment.

- **Misconception 2: Scientific theories are facts.** In his book "The Meaning of It All," Nobel Prize-winning physicist Richard Feynman states "Scientists, therefore, are used to dealing with doubt and uncertainty. All scientific knowledge is uncertain." (page 26). Scientific theories, such as the kinetic-molecular theory of matter (taught in the grade 7 heat unit), are models that help explain how our world works, not absolute truths. Good theories are effective in explaining what we observe, and in predicting outcomes in novel situations. When a theory fails to accurately predict something, the theory must either be modified or discarded. (In contrast, students often feel compelled to modify their observations or results to fit the theory – a side-effect of the "theories as facts" misconception). All theories that are generally accepted in science today have gone through an extensive process of revision and testing; however, even a long-standing theory can be overturned by a single conflicting piece of evidence. Students must be made aware of the dynamic nature of

theory making: "Our instruction in science from start to finish should be mindful of the lively processes of science making, rather than being an account only of "finished science" as represented in a textbook" (Bruner, 1996, page 127). Constructivist classroom activities, where students are actively building knowledge, testing theories and modifying them as necessary, gives an authentic view of how science and theory making occur in the real world.

- **Misconception 3: Science is a linear process**. The "scientific method" is a useful and standardized framework in which to publish the results of scientific inquiries, but it is not how science is conducted. Unfortunately, many students are turned off science because hands-on work is presented as a rigid, linear process, where every activity regardless of how trivial, follows a carefully scripted procedure and the teacher places a painful emphasis on recording and reporting. Deviation and creativity are rarely tolerated, let alone encouraged. "Real" science tends to be much messier. Students must certainly be taught experimental design, the value of controls, observational skills, the value of recording results, and other skills needed to make their experiments valid. But they must also learn that in scientific inquiries:

  i) Experiments don't always end up as planned.
  ii) Procedures don't always work
  iii) Unexpected results can lead to a valuable insight or understanding.

- **Misconception 4: Scientists (and teachers) have (or are expected to have) all the right answers.** Most accounts of science history highlight the successes –- those famous experiments that helped extend knowledge and led to influential theories. Students (and teachers) often do not realize that scientists regularly come up with, ideas, conclusions and theories that appear to be correct but turn out to be wrong. The teaching of science and technology needs to acknowledge that scientists, like teachers and everyone else, are sometimes wrong, and sometimes don't have answers to important questions. What is "right" in science results from a process of creative investigation, lively debate and consensus. An effective science classroom mirrors this process. There is no master book of answers — if there was, there'd be no need for science and technology at all. If you need further evidence for how scientific ideas are constantly changing, look up almost anything scientific in a 20, 30, or 50-year-old encyclopedia! (This is a good activity for students too!)

"Learning often requires more than just making multiple connections of new ideas to old ones; it sometimes requires that people restructure their thinking radically. That is, to incorporate some new idea, learners must change the connections among the things they already know, or even discard some long-held beliefs about the world."

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Learning to Generate Questions & Design Problems

A simple but effective way to help students generate questions is to introduce a template that frames questions in the following format:

"How does ___ affect ___?"

During a unit of study, questions framed in this way by the teacher can be used as the focus for short labs and investigations. For example, in the grade 7 heat unit, students could investigate the question "How does temperature affect the bounce height of a tennis ball?" Students can conduct the inquiry, and as a follow-up, they can be challenged to use the kinetic-molecular theory to help them explain WHY they got the results they did. Once students become familiar with this format, they can start developing and investigating questions of their own.

Putting questions in this format has two advantages for students. First, the question looks for a correlation between two variables: How does changing the first variable affect the second variable? Secondly, questions in this format clearly define the independent and dependent variables. The first variable, the one that will be changed by the student, is the independent variable. The second variable is the dependent variable, the one that will be measured. In the bouncing ball example, the temperature of the ball is the independent variable. How high the ball bounces is the dependent variable. Identification of the independent and dependent variable can often be a problem for students at the grade 7/8 level. This simple question format can help students develop genuine questions that can form the starting point for both small and large independent investigations.

"Technology extends our abilities to change the world: to cut, shape, or put together materials; to move things from one place to another; to reach farther with our hands, voices, and senses. We use technology to try to change the world to suit us better."

American Association for the Advancement of Science. Science for all Americans.

The idea of correlation can also lead to discussions of the difference between correlation and causation. Correlation between variables may imply, but does not prove, causation. In other words, a relationship between two variables (correlation) does not necessarily mean there is a cause-and-effect relationship (causation). Other, possibly unknown, factors may be contributing to the phenomenon being studied. An understanding of correlation is essential for students to appreciate and discuss many current scientific issues. Medical studies, in particular, often come under attack because they are correlational. (The high correlation between cigarette smoking and lung cancer is a classic example. Critics dismiss these findings because they do not prove causation, and cite examples of long-lived, cancer-free smokers as evidence against causation.) Students, teachers, and the public need to appreciate that much of science is the search for consistent, reproducible patterns (a direct connection to mathematics) and that 100% certainty is exceedingly rare.

Helping Students Find Ideas

For students, often the most difficult part of a science or technology project is coming up with a topic. There are several things that teachers can do to help students develop project topics:

i) **Look for a general topic, and then narrow it down to a specific question/problem.** Most science and technology projects can be framed as a question. If students have a general topic of interest, they can look for a specific question, or two related questions, to answer. The major advantage of generating a specific question is that it gives students a focus. Although the format outlined in the previous section (How does _____ affect _____?) appears to be simple, the questions generated in this format can be quite sophisticated and can require considerable work and planning to answer. In addition, students who start out with a relatively simple question will often generate several other questions as they conduct their inquiry.

ii) For technology projects, it is a good idea to encourage students to look for a specific problem to solve. As with experimental topics in science, students looking at technology projects can find many ideas in class and in everyday life. Technology deals with finding solutions to human needs, arising from interactions with their natural and human-made environment. Re-designing products to improve their performance, creating products to solve a specific need, or looking at the performance attributes of a product to examine strengths and weaknesses are all ways to generate technology projects.

A good example of a technology project that arose from personal interest or everyday experience comes from Kyle Norman of London, Ontario, who attended the Canada Wide Science Fair in 2002:

Wind - The Invisible Force

After viewing a film about the Tacoma Narrows bridge collapse in 1940, I was inspired to build a wind tunnel to investigate the aerodynamic instability encountered by suspension bridges. Could they be improved? My experiment concluded that the addition of wedge shaped fairings on the leading edge of the bridge deck increased its aerodynamic stability.

iii) **Teach Students to Read Critically, and Question What They Read.** When students are reading a textbook, they should be encouraged to think critically about what is written. Textbooks and other resources can be a rich source of information, and a rich source of questions for students who read critically and thoughtfully. For example, if a book says that the temperature at the core of the sun is 6000∞ Celsius, many possible questions come to mind: "How do scientists know the temperature in the middle of a star?"; "What instruments do scientists use to measure the temperature of a star?"; "How does the temperature of a star affect its colour?"; "How much does the temperature vary in different parts of a star?", or, "Do scientists know the core temperatures of all stars, or just the sun?"… you get the idea. Students who are engaged and encouraged can take the simplest activity or paragraph and come up with dozens of questions. This works particularly well in small groups.

iv) **Provide a Wide Range of Activities in the Science and Technology Program.** A balanced science and technology program, with readings, research, discussions, experiments, demonstrations, videos, and other activities will provide many opportunities for students (and teachers) to develop questions. In their notebook, students could have a page at the front or back of the unit where they record questions that come to mind over the course of the unit.

v) **Encourage Students to Pick Topics in an Area of Personal Interest.** Project ideas that arise from work in class, or from students' own lives and interests, are the most interesting and relevant for students. A science and technology program that promotes questioning and curiosity will encourage students to see science questions and problems in every aspect of their daily lives.

vi) **Give Students Enough Time!** Ensure that students are aware early in the unit, or early in the year, that they will be responsible for an independent project. This will allow students to be looking for questions throughout the unit. Particularly if the selection of project topic is to be open-ended (not confined to a specific unit of study), encourage students to read about current science and technology issues in

the news. Students could also be required to present an oral report to the class about a current issue. The report could include definitions of relevant concepts, an outline of what the issue is, and why the issue is significant. These presentations could lead to questions that students could investigate further in a project.

vii) **Encourage Students to Question! Science Topics are Everywhere.** During a unit of study, students often come up with interesting questions during activities, discussions and readings. These can be recorded on cards or chart paper, then posted in the room. Later, students can review these questions for project ideas, especially if the project serves as a culminating activity.

viii) **Think of Questions From Other Curriculum Areas.** Believe it or not, for some students science and technology is not their favourite subject! Encourage these students to look at different subjects, such as mathematics, computers, art, or music. For example, an interest in music can lead to projects about acoustics, sound waves, harmony, or computer-generated music.

Displaying a Project

An attractive, logically displayed project can have a big impact on how the project is perceived. Some ideas for students to consider when planning a display include:

> **"There are no mistakes, no coincidences. All events are blessings given to us to learn from."**
>
> Elizabeth Kubler-Ross

i) A catchy title that is relevant and clever can grab people's attention
ii) Use appropriate graphs to visually display data and show trends in the results
iii) Display equipment used in the experiment
iv) Use photos to show steps of your design process, and to display results
v) Have clearly labeled sections that show your focus question or design problem, concepts, procedure, results, answers to the focus question, and applications
vi) Excellent grammar, spelling, punctuation, and neatness are very important

Regional science and technology fairs have an extensive list of safety rules that detail what can or cannot be used or displayed in a project. Contact your regional fair to get a complete list of rules. For example, if a region follows the Canada Wide Science Fair safety rules, live plants are not allowed to be displayed. Photos should be used instead.

Modifications and Adaptations

1) Exceptional students – gifted

Science and technology projects are an ideal vehicle for the differentiation of the curriculum, and the provision of enrichment and challenge for gifted students. While gifted students require classroom experiences that develop inquiry and design skills, many will grasp these concepts quickly and easily and should be encouraged to apply them in their own investigations as early and as often as possible. Gifted students can more readily appreciate the tentative and ever-changing nature of science and can be captivated by the notion that scientific knowledge is a human construction rather than a set of universal truths. A content-based approach and/or an emphasis on rigid procedures and reporting is particularly inappropriate for gifted students, who tend to thrive on the opportunity to challenge, discuss, and hypothesize. As with other students, project-based science and technology should be a component of the classroom program for gifted students – teachers should resist the temptation to

interpret 'project' as meaning 'at home.' All students need guidance and advice through the course of their project; this is most consistently and equitably available in school.

2) Exceptional Students - other

Students with identified exceptionalities can benefit from project-based science programs. The key is ensuring that the expectations, assessment and evaluation are appropriate for the student. Exceptional students can be paired with another student who has complementary skills, allowing the exceptional student to use his/her strengths to contribute in a meaningful way. For example, a student with a written language exceptionality can take the lead in discussing and planning an project, and can contribute to the reporting using their relative strengths in reading and oral and visual communications. Their partner can write up the procedure they developed, and record the results. If a student has difficulty writing, then they should be encouraged to explain an individually completed project to a teacher or judge orally.

Exceptional students can also benefit from extra teacher assistance, as many students will be able to work independently and will require only occasional assistance.

3) ESL/ESD Students

Project-based science is an ideal format for ESL/ESD students to demonstrate understanding in a concrete way. The "hands-on/minds-on" nature of project work allows for vocabulary to be introduced and developed in a contextual and meaningful way, with the help of English-speaking peer tutors to support student learning. These tutors provide opportunities for conversations that are curriculum-based and *interesting* to ESL/ESD students and take place in a non-threatening, natural atmosphere.

Depending on the Stage of language proficiency, ESL/ESD students can be responsible for less language-intensive aspects of the project, such as the design and building of models, pictures, graphs, maps, charts, and artistic layout of the project. Additional teaching and assessment/evaluation strategies can be found in the Ontario Ministry of Education's English as a Second Language and English Literacy Development: A Resource Guide (2001). As well, sample adaptations and modifications for selected science units can be found in the document (Grade 2 Movement, Grade 5 Weather, Grade 8 Optics).

"There are many examples of old, incorrect theories that stubbornly persisted, sustained only by the prestige of foolish but well-connected scientists. ... Many of these theories have been killed off only when some decisive experiment exposed their incorrectness"

Michio Kaku, Hyperspace, Oxford University Press, 1995, p 263.

Whose Project Is It?

1) Parent Involvement

One concern often raised about science fair projects is based on the classic image of the father or mother who slaves away to complete their child's science project, or the parent whose focus on winning overshadows the project's benefit to a child's developing inquiry and design skills. This concern is legitimate, and must be addressed.

It is important early on in the process to involve parents, and to help them understand what their role should be. Like a teacher, parents can be a great resource, helping students get materials and equipment, giving advice and suggestions, and helping build the skills needed to complete a project. Parents can also be a good sounding board to bounce ideas off, as students try to make meaning out their results and explain the "whys" and "hows" of their project. However, parents (and students) need to be told

quite clearly that the project is to be the work of the student and that excessive parental involvement makes it difficult or impossible to assess and evaluate the student's achievement of the relevant expectations. This is the primary reason for science and technology projects to remain school-based and for the teacher to establish a clear sequence of assessment events to provide ongoing feedback to the student (and parent) on the project's progress.

A series of brief discussions with a student will usually reveal his/her involvement in and understanding of the project. If a parent has done most of the work, the student usually lacks understanding about what was done, why it was done, and exactly what the results mean. Above all, in a competitive situation, such as a science and technology fair, it is vital that the excellence of student work (and not the work of parents) is recognized and celebrated. The message of what is valued is more clearly communicated to parents and students by who is selected for recognition than by any other means.

2) Mentors

Some students who are serious about their work in science and technology may choose to seek the help of a mentor in developing their project. Many people working as professionals in a scientific field, at private companies, teaching hospitals or universities are willing to serve in this role for students, even those in grade 7/8. Co-op students from high schools and universities can also make excellent mentors in an elementary school. These mentoring opportunities allow students access to expertise, equipment and resources that would otherwise be unavailable to them. However, the involvement of mentors must be monitored, and their role should be clearly defined prior to beginning work on the project:

i) The project should begin with a question-generating process by the student. Ideally, a mentor should not become involved until after the student has formulated his/her question. It is important that the student be doing his/her own project and not simply helping with a project of a mentor.
ii) Be sure to inform the mentor that the work being conducted is part of the student's evaluation, so the student must do the primary work.
iii) The mentor and student should record what the mentor's contribution to the project was, and the mentor should sign it.
iv) If specialized equipment is used that is beyond the skill or knowledge of the student to use, they should be involved as much as possible in reading and interpreting the results (e.g. using a mass spectrometer)

As the name implies, a mentor should be available for guidance and to share his/her expertise with the student conducting the research. Like parental involvement, a mentor who is too involved in the project will have detrimental effects on the skills development and understanding of the student. (As some parents may also act as mentors, the guidelines for Parent Involvement and Mentors may need to be reviewed together in some cases.)

What Makes a Great Project?

Ellen, a grade 7 student, lives on the Scarborough Bluffs. She watches, year after year, as her backyard slowly disappears from soil erosion. Ellen decides to do a project on this topic: Do different techniques for preventing erosion have an impact on the rate of erosion? She does some research and learns about the different techniques used to help slow erosion. Then, she builds a homemade wave machine and tests the different techniques on different soil types. She wins first prize at her school and regional fair, and goes to the Canada Wide Science Fair.

Ellen's project exhibits many of the characteristics of a great project:

i) Interesting and relevant question
ii) Creative method for answering the question
iii) Thorough background research and understanding of topic
iv) Sound experimental design with variables controlled to best of students' ability

Sometimes, defining what makes a great project can be elusive. However, the most important part of a project tends to be an engaging question or problem from which to begin.

A Project in Stages

For most students, designing and conducting an independent project is a daunting task. Breaking it into manageable sections and providing feedback at each of the stages is invaluable. Because students in grade 7/8 are still developing the skills of inquiry and design, working with them through each stage of the project will help ensure that the process runs more smoothly and students remain headed in the right direction. Students can be given a checklist that gets signed by the teacher (student and parent) as each stage of the project is successfully completed. The checklist can include important reminders for students to keep in mind as they work on each stage. Sections could include: topic, focus question or design problem; developing a methodology for the inquiry or design (experiment, correlational study, observational study, research, or innovation); collecting and displaying data, results or recording the design process; analysis of the findings or testing of the design; and future applications and implications of the work.

Assessment Rubrics

Assessment of student projects will depend on the context in which the projects were done. Projects done in class as a culminating activity for reporting purposes must be assessed using expectations from the Ontario curriculum. In the Appendix, you will find several assessment rubrics from the Assessment of Science and Technology Project. These can be used individually, or parts from two or more can be combined to create a customized rubric that assesses skills from several different areas.

If your students are doing projects around a particular unit of study, assessment rubrics can also be generated using the specific expectations from that unit. The rubric could then combine skills of inquiry and design, expectations about relating science and technology to the world, as well as specific content from the unit.

For integrated projects, where assessment will occur in more than one subject, the Ontario Curriculum Unit Planner is a valuable tool. It allows you to generate a rubric using expectations from various subject areas.

Projects done as co-curricular projects can be assessed using the rubric from the Canada Wide Science Fair (see Appendix).

Where Can Great Grade 7/8 Projects Go?

School or Classroom Science and Technology Celebration
The vast majority of students and projects will not go beyond the classroom or school. That is OK! Science projects are intrinsically rewarding, and displaying them for the class or school can and should be a positive experience.

Regional Science & Technology Fairs
In Ontario, there are 28 Regional Science and Technology Fairs. Organized by volunteers, these events are a great venue for young scientists to showcase their work and to experience the wide variety of scientific and technological work of their peers. A listing of the regional fairs is available at the Sci-Tech Ontario website: www.scitechontario.org.

"The technologies which have had the most profound effects on human life are usually simple."

Freeman Dyson, Infinite in All Directions, Harper and Row, New York, 1988, p 135.

Canada-Wide Science Fair
The best young scientists from the Regional Science and Technology Fairs in Ontario are selected to attend the week-long Canada Wide Science Fair as members of 'Team Sci-Tech Ontario.' Youth Science Foundation Canada (YSF) coordinates this annual event, which is held in a different host city each year. For more information, visit the YSF website at: www.ysf.ca.

Other Opportunities
A well-balanced science and technology program will help develop students who are critical thinkers, with good problem solving, inquiry, and design skills. For these students, there are opportunities outside the classroom to further develop their skills and have fun with science and technology:

ENO Canadian National Marsville Program
The purpose of the Canadian National Marsville Program is to create a positive vision for young Canadians of the technological society that will inherit in the 21st century. The program shows students how they can play a role in establishing the kind of society they want for the future. Marsville has been designed for students in Grades 5 to 12. While the primary educational thrust of Marsville is math, science and technology, the project uses a cross-curricular, holistic approach integrating various disciplines. For more information, visit their website at http://mars2002.enoreo.on.ca/

ENO Robotics Challenge
The Robotics Challenge is a unique multi-year educational project aimed at students in grades 4 to 12. It provides opportunities to learn about science, technology, math and design through the development, programming and testing of autonomous robotic devices. For more information, visit their website at http://challenge.enoreo.on.ca/

Real Science: A Summary
Using Projects to Engage Students and Meet the Goals Of the Ontario Curriculum

Providing a meaningful and engaging science and technology program is a challenging task. Project-based science and technology is the natural culmination of a program that involves students in developing inquiry and design skills, and that helps students to connect science and technology to each other and the outside world. Through authentic investigations, students construct an understanding of how science works, and develop critical thinking skills that will serve them well in their future endeavours. Important connections exist between projects, a classroom program that is both hands-on and "minds-on and the Ontario Curriculum in science and technology:

- Projects effectively address the 3 overall goals of science and technology education.
- Projects integrate many curriculum expectations in science and technology.
- Projects are an effective culminating assessment activity for a unit.
- Inquiry and design skills needed to complete a project are found in the expectations for every unit of the Ontario science and technology curriculum.
- Project-based science and technology incorporates constructivist learning, and encourages students to explore the important questions and concepts related to a topic.
- Project-based science and technology can be used to integrate knowledge and skills from many different curriculum subjects.
- Common misconceptions about science and technology often hinder effective science and technology instruction and independent project work.
- How does _____ affect _____? is an effective framework for generating inquiry and project questions.
- Strategies are available for helping students develop inquiry and project ideas.
- Tips on displaying a project can help students communicate their work.
- Project-based science and technology can benefit students with exceptionalities.
- The role of parents and mentors in projects must be clearly explained.
- Several key features distinguish a great project.
- Students can complete a project in stages, breaking it down to manageable pieces.
- There are many exciting opportunities for students involved in project-based science and technology.

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Feynman, R.P. The Meaning of it All: Thoughts of a Citizen-Scientist. Reading, Massachusetts: Perseus Books, 1998.

Ontario Ministry of Education and Training. The Ontario Curriculum, Grade 1-8: Science and Technology. Toronto: Queen's Printer for Ontario, 1998.

Ontario Ministry of Education and Training. English As a Second Language and English Literacy Development - A Resource Guide, 2001. Toronto: Queen's Printer for Ontario, 2001.

Wiggins, G., and McTighe, J. Understanding by Design. Alexandria, Virginia: Association for Supervision and Curriculum Development, 1998.

Appendix One:
STUDENT HANDOUTS

Science and Technology Projects
HELP I DON'T HAVE A TOPIC!

As mentioned in class, this is the hardest part of an investigation for most people. Don't give up! There is lots of help available for you. Follow the steps below to help you come up with a topic, but keep one thing in mind: Choose a topic that is of INTEREST TO YOU!! It will make it much easier to work steadily and achieve a good result!

1) Begin with Your Own Interests

Science is a part of every aspect of your life, whether you know it or not. Begin with your own interests--if you enjoy music, consider an investigation into sound (What gives each instrument its characteristic sound?; How does the material of a string affect the sound produced?)

If you like history, perhaps you can research an experiment by an early scientist and repeat it yourself. If you are an artist, you can examine processes like silkscreening or ceramics--these areas contain many topics of scientific value!

Without listing every possible interest here, it should be obvious to you that your own interests can lead to interesting investigations. In the spaces below, list 4 or 5 general areas of interest for you:

_____

_____

_____

_____

_____

_____

_____

_____

_____

2) Research/Investigate the Topic

From your list of interests, choose one topic that you think might lead to an interesting science inquiry.

Then use the public library, CD-ROMs, or classroom resources to develop a specific question about the topic.

Note that classroom resources are listed on the chart paper at the front of the room.

In the spaces below, please list the resources you used, including specific page numbers. Two resources is the minimum you should use.

(Example: Gleick, James. Chaos. pp. 47-63.)

_____

_____

_____

_____

3) Develop a List of Possible Focus Questions from Your Research and Select One.

A good focus question is specific and clear, and avoids having YES or NO for an answer. A good format for your question is:

How does _____ affect the

_____ of _____ ?

This format creates a simple cause and effect question. Does one thing (independent variable) have an effect on another (dependent variable)?

Some examples:

How does <u>temperature</u> affect the <u>bounce height</u> of a <u>tennis ball</u>?

How does <u>wind direction</u> affect the <u>pH of rainfall</u> in <u>Scarborough</u>?

An important feature of a good question is that it suggests some method of answering it! In both examples, you can probably think of a method that could be used to help answer the question.

A good question also tells you what NOT to do. In the first example, you would not test the bounce height of an India-rubber ball. Although it might be interesting, it is not part of the investigation question. If you changed the question to "How does heat affect the bounce height of balls?", then testing an India-rubber ball and others would make sense. Changing just one word can make your investigation quite different!! Take time to develop a good focus question, and don't expect your first version to be the final one. Check your question with other students and with me, and check with me before you use it for your project.

NOTE: There are other possible formats for your question as well, such as:

How does the violence in police/crime shows of the 60's compare to 2000?

How can the freezing temperature of water be changed from 0°Celsius?

The format described above (How does _____ affect the _____ of _____ ?) is a simple, effective way to formulate a good question, but not the only way.

Your focus question is due on

_____

?

Science and Technology Projects
I HAVE A FOCUS QUESTION.....NOW WHAT?

Now that you've developed a focus question, it's time to thoroughly plan what you will do for your project. Careful planning is essential for a successful project. The attached Project Outline has sections to fill out important information about your project, things you'll need to think about and know before you begin the actual "hands-on" science. They may change as your experiment progresses, but good planning at the start can save you work, and trouble, later.

a) Focus Question

This should be your final focus question for your project and should be worded clearly. Make sure it can be answered, and avoid yes/no types of questions. See the previous section for more details. If possible, put it in the form of

How does _____ affect _____.

The first blank is the variable you will change, and the second is the variable you will observe.

b) Concepts

You should have a complete list and description of all the concepts (ideas) that are related to your topic.
This might require some additional research, and can include research you did as you developed a focus question

c) Procedure and Materials/Equipment

In this section, you describe exactly what you are going to do in order to answer the focus question. It should be detailed enough that another student at your level could read the procedure and conduct the experiment. A list of all necessary materials and equipment should also be given.

The Project Outline is due for all classes on:

_____

This will give you plenty of time to conduct the experiment, record results, prepare transformations of your results, and write your knowledge and value claims (what you learned and why it is important). More on that will come up in the next handout. For now, you should have enough on your plate to keep you busy!

Science and Technology Projects
PROJECT OUTLINE

Student Name: _____

Partner's Name (if applicable): _____

Type of Project (check one): Experiment ❑ Study ❑ Innovation ❑

Focus Question:

_____

_____

_____

_____

Other Related questions I have:

_____

_____

_____

_____

How I plan to answer my question(s):

_____

_____

_____

_____

_____

Scientific Concepts involved (list and define them):

_____

_____

_____

_____

Special Requirements/Equipment needed

_____

_____

_____

Science and Technology Projects
TRANSFORMING AND DISPLAYING YOUR DATA

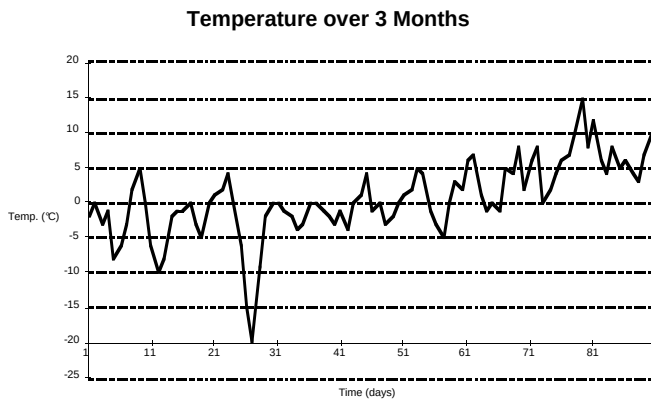
Transformations are a very important part of any scientific presentation. Their purpose is to transform large amounts of data into an easily understood form that displays some interesting aspect of the data. Graphs are probably the most common form of transformation, but they are often misused. Two of the most useful graphs for scientific work are line graphs and bar graphs.

Example:

Suppose you measured the temperature every day for three months. You'd have about 90 pieces of data that aren't very interesting on their own. Further, it would be difficult to see any sort of pattern. "A graph would help." you think, but what type of graph? "What does it matter, a graph's a graph, isn't it?" Actually, no. The type of graph you make depends on your data, how you've organized it, and what you're trying to show.

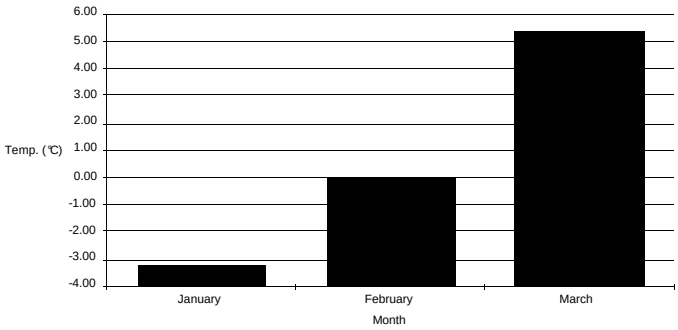
Line Graphs

Line graphs are probably the simplest, because they usually show all the data points and the data are not organized in any way before making the graph; however, one thing must be true about the data in order to use a line graph: The scale on both axes of the graph must be continuous, that is, the data could have any value on them. For example, on our "Temperature over 3 Months" graph, if the x axis represents time in days, the data could have any value on the scale: 2 days, 5.56 days, 1.004 days. Of course the temperature could be any value as well. This graph shows the temperature record rather well, but if you were simply trying to show that the temperature increased gradually over the three months, there's too much data here – the pattern is obscured.



Bar Graphs

Another possible transformation to show this trend more clearly would be to group the data into the three months, calculate an average, and graph these 3 values. As soon as you group the data (or if the data are already grouped) you cannot use a line graph. On the x axis now you'll put January, February, March. These are categories and they are not continuous – a day is either in January or February, it cannot be any value in between. Data in categories or groups are shown on a bar graph.



Science and Technology Projects
CHECKLIST FOR REPORTS OF SCIENCE & INVENTION[1]

For all major reports of science or invention, use the following general format:

TITLE
- The title is related to the question/problem being studied.

INTRODUCTION
- This section is written in paragraph form.
- The question or problem being attempted to be solved is stated.
- Some predictions, with reasons (hypotheses) are mentioned.
- The most likely prediction is explained (with reference to outside sources).
- A brief summary of the over-all methods is mentioned.

MATERIALS AND METHODS
- All materials used in the project are listed.
- All methods are listed in numbered steps (like a "recipe").
- There is evidence of proper attention to 'Test Design Factors'; i.e.
- A wide range, with many values, of the possible cause variable under study.
- All variables were measured in at least two ways, where possible.
- Possible cause variables besides the one of interest were controlled.
- All tests and measurements were repeated an appropriate number of times.
- Qualitative descriptions of objects and events are conducted.
- A diagram or sketch of the methods is included.

OBSERVATIONS AND RESULTS
- All observations and results are reported.
- All observations are organized into appropriate tables, charts, and/or graphs.
- Any calculations which were necessary are shown.

DISCUSSION
- This section is written in paragraph-form, as a continuation of the INTRODUCTION
- A qualitative and/or quantitative description of all results is given.
- A critical evaluation of the actual methods, according to 'Test Design Factors,' is given.
- A careful conclusion about the value of the original prediction, with reason(s), is given. .
- Possible applications of the conclusions are discussed.
- Further work in science and/or invention which might be done in the future are discussed.

GENERAL LAYOUT
- The document is neatly printed, written or typed (not absolutely necessary).
- The document consists of the four sections, as indicated above.
- All references are properly noted in the "Endnotes"
- A complete and correctly alphabetized "Bibliography" is present.

TEACHER'S COMMENTS (over):

Appendix Two:
ASAP RUBRICS

Assessment of Science and Technology Achievement Project

Communication Rubric

Criteria	Level 1	Level 2	Level 3	Level 4
Communication of required knowledge ***MET (page 13)***	*- communicates with little clarity and precision;* *- rarely uses appropriate science and technology terminology and units of measurement;*	*- communicates with some clarity and precision;* *- sometimes uses appropriate science and technology terminology and units of measurement;*	*-generally communicates with clarity and precision;* *- usually uses appropriate science and technology terminology and units of measurement;*	*- consistently communicates with clarity and precision;* *- consistently uses appropriate science and technology terminology and units of measurement;*
Clarity and precision of supporting evidence	communicates information without stating the question or problem that was solved and states conclusions that are not supported with adequate evidence uses tables, charts and/or diagrams but their purpose is unclear	communicates information describing the question or problem that was solved and states conclusions with some supporting evidence uses some tables, charts and/or diagrams and their purpose is clear	communicates information describing the question or problem that was solved and states conclusions with an adequate amount of evidence uses tables, charts and/or diagrams where appropriate and their purpose is clear	communicates information clearly describing the question or problem that was solved and states conclusions with specific and detailed evidence uses tables, charts and/or diagrams in appropriate contexts and their purpose is clear
Clarity and precision of vocabulary including mechanics	uses colloquial language in place of proper science or technology terminology major errors in spelling and /or grammar that interfere with meaning	uses some colloquial language in place of proper science or technology terminology major errors in spelling and/or grammar, but meaning is clear	usually uses proper science or technology terminology in proper context minor errors in spelling and/or grammar but meaning is clear	consistently uses proper science or technology terminology in proper context no errors in spelling and/or grammar and meaning is clear
Clarity and precision with measuring	records numerical data inaccurately and inconsistently which affects the results of the investigation attempts calculations but they are incomplete and/or incorrect uses incorrect SI units or often does not include any units or symbols constructs graphs with assistance	records numerical data consistently but with some errors in accuracy which affects the results of the investigation completes calculations but some calculations are incorrect leading to erroneous conclusions uses SI units using words or a mixture of words and symbols with some incorrect units constructs graphs with some assistance	records numerical data consistently but with minor errors in accuracy which do not affect the results of the investigation completes calculations with some minor errors which do not lead to erroneous conclusions uses SI units with symbols with an occasional incorrect unit constructs graphs with some minor errors	records numerical data consistently and accurately completes calculations correctly consistently uses correct SI units with symbols; constructs accurate graphs

Assessment for Science and Technology Achievement Project

Understanding Basic Concepts

Criteria	Level 1	Level 2	Level 3	Level 4
Understanding of basic concepts ***MET (page 13)***	*-shows understanding of few of the basic concepts* *-demonstrates significant misconceptions* *-gives explanations showing limited understanding of the concepts*	*- shows understanding of some of the basic concepts* *- demonstrates minor misconceptions* *-gives partial explanations*	*- shows understanding of most of the basic concepts* *- demonstrates no significant misconceptions* *- usually gives complete or nearly complete explanations*	*- shows understanding of all of the basic concepts* *- demonstrates no misconceptions* *- always gives complete explanations*
Understanding of relevant concepts, principles and theories	demonstrates significant misconceptions which detract from the meaning when explaining concepts, principles or theories does not identify or explain sources of error	demonstrates minor misconceptions which do not detract from the meaning when explaining concepts, principles or theories identifies but does not explain sources or error	demonstrates no significant misconceptions when explaining concepts, principles or theories identifies and partially explains sources of error	demonstrates no misconceptions or revises prior misconceptions when explaining concepts, principles or theories identifies and explains sources of error
Applying relevant concepts, principles and theories	analyses information in a way that shows some contradictions or confusion evident in their use of the concepts	analyses, interprets and evaluates information in a way that shows an occasional contradiction or confusion in the use of concepts;	analyses, interprets, and evaluates information in a way that essentially shows an understanding of the concepts;	analyses, interprets, and evaluates information in a way that shows a clear understanding of concepts;
Explaining concepts, principles and theories	gives explanations that are incomplete, inaccurate and lack detail	gives explanations that have major errors in accuracy and lack detail	gives explanations that are complete and accurate but the level of detail is inconsistent	gives explanations that are complete, accurate and detailed

Assessment for Science and Technology Achievement Project

Design Rubric

Criteria	Level 1	Level 2	Level 3	Level 4
MET (page 13) ***Inquiry and design skills***	*- applies few of the required skills and strategies*	*- applies some of the required skills and strategies*	*- applies most of the required skills and strategies*	*- applies all of the required skills and strategies*
Initiating and Planning *Understanding the need* *Making a plan*	- does not demonstrate an understanding of the problem; -no plan is attempted for designing a product, or the plan is incoherent or unworkable; - does not take into account predetermined criteria;	- demonstrates a partial understanding of the problem; - develops a plan for designing a product that is limited in appropriateness, efficiency, clarity, and completeness; - identifies and takes into account some predetermined criteria;	- demonstrates a basic understanding of the problem; - develops a plan for designing a product that is appropriate, clear and complete; - identifies and takes into account most predetermined criteria;	- demonstrates a thorough understanding of the problem; - develops a reproducible plan for designing a product that is appropriate, efficient, clear, and complete; - identifies and takes into account all predetermined criteria;
Performing and Recording *Carrying out the plan*	- does not follow a plan to build a product; - needs assistance to select appropriate materials and equipment to build a product; - tests the product and records results that are irrelevant or not related to predetermined criteria; - makes no modifications or re-testing of the product; - display of information is disorganized, not precise, accurate or complete; - units are not indicated;	- follows most steps in a plan to build a product; - selects appropriate materials and equipment to build a product; - tests the product and records results that are limited in scope, contain major inaccuracies or have limited relevance to predetermined criteria; -makes modifications but does not re-test product; - display of information is somewhat organized, and somewhat precise, accurate and complete; - units are often incorrect or are not included;	- follows all steps in a plan to build a product, and makes required modifications; - selects appropriate materials and equipment to enhance the performance and design of the product; - tests the product and records results with sufficient scope and detail that are relevant to predetermined criteria; -makes and records modifications and retests product; - display of information is organized and mostly precise, accurate and complete; - most units are included;	- follows all steps in a plan to build a product, and makes and records required modifications; - selects appropriate materials and equiment and adapts materials to enhance the performance and design of the product; - tests the product and records results with extensive scope and detail that are relevant to predetermined criteria; -makes, records and justifies modifications, and re-tests product; - display of information is organized, precise, accurate and complete; - all units are included;
Analysing and Interpreting *Looking back*	-relevant criteria are not analysed or explained; -conclusion/ inference is absent, incoherent, illogical, or irrelevant, and not supported by the performance of the design; - product does not address the original problem;	-relevant criteria are partly identified and explained, without analysis; -conclusion/ inference is not well supported by performance of the design; or is partially supported performance and is not clearly stated; - product partly addresses the original problem;	-relevant criteria are identified and explained with partial analysis; -conclusion/ inference is valid, understandable and supported by the performance of the design; - product addresses the original problem;	-relevant criteria are identified, analysed and explained; -conclusion/ inference is valid, clearly stated and well supported by the performance of the design; - product fully addresses the original problem;

Assessment for Science and Technology Achievement Project

Inquiry Rubric

Criteria	Level 1	Level 2	Level 3	Level 4
MET (page 13)	*- applies few of the required skills and strategies;*	*- applies some of the required skills and strategies;*	*- applies most of the required skills and strategies;*	*- applies all (or almost all) of the required skills and strategies;*
Initiating and Planning *Understanding the need* *Making a plan*	- states questions in an untestable form and identifies few of the components needed for a fair test; -no set of procedures is attempted, or the procedures are incoherent or unworkable; - does not identify or control variables;	- restates questions in a testable form that identifies some components needed for a fair test; - develops a set of procedures that are limited in their appropriateness, efficiency, clarity, and/or completeness; - identifies and controls some variables;	- restates questions a testable form that identifies most components needed for a fair test; - develops a set of procedures that are appropriate but are limited in their efficiency, clarity, or completeness; - identifies and controls most major variables;	- restates questions in a testable form that identifies the components needed for a fair test; - develops a set of procedures that are appropriate, efficient, clear, or complete; - identifies and controls major variables;
Performing and Recording *Carrying out the plan*	- does not follow any procedures to conduct a fair test; - data are not recorded or is irrelevant; - display of information is disorganized, not precise, accurate or complete; - units are not indicated;	- follows most identified procedures to conduct a fair test; - data are of limited relevance, is limited in scope, and/or contains major inaccuracies; - display of information is somewhat organized, and somewhat precise, accurate and complete; - units are often incorrect or are not included;	- follows identified procedures to conduct a fair test, and makes some modifications; - data are relevant and sufficient in scope and detail, but not extensive; - display of information is organized and mostly precise, accurate and complete; - most units are included;	- follows identified procedures to conduct a fair test, and justifies modifications; - data are relevant and may be extensive in scope and detail; - display of information is organized, precise, accurate and complete; - all units are included;
Analysing and Interpreting *Looking back*	-relevant data are not analysed or explained; -conclusion/ inference is absent, incoherent, illogical, or irrelevant, and not supported by the data; - conclusion does not address the original task;	-relevant data are partly identified and explained, without analysis; -conclusion/ inference is not well supported by the data; or is partially supported by the data and is not clearly stated; - conclusion partly addresses the original task;	-relevant data are identified and explained with partial analysis; -conclusion/ inference is valid, understandable and supported by the data; - conclusion addresses the original task;	-relevant data are identified, analysed and explained; -conclusion/ inference is valid, clearly stated and supported by the data; - conclusion addresses the original task;

Assessment for Science and Technology Achievement Project

Relating Science and Technology Rubric

Criteria	Level 1	Level 2	Level 3	Level 4
Relating of science and technology to each other and the world outside the school ***MET (page 13)***	*shows little understanding of connections between science and technology in familiar contexts;* *shows little understanding of connections between science and technology and the world outside the school;*	*shows some understanding of connections between science and technology in familiar contexts;* *shows some understanding of connections between science and technology and the world outside the school;*	*shows understanding of connections between science and technology in familiar contexts;* *shows understanding of connections between science and technology and the world outside the school;*	*shows understanding of connections between science and technology in both familiar and unfamiliar contexts;* *shows understanding of connections between science and technology and the world outside the school, as well as their implications;*
Interpreting and applying concepts	shows little evidence of interpreting and applying concepts and principles in familiar situations	shows some evidence of interpreting and applying concepts and principles in familiar situations	shows sufficient evidence of interpreting and applying concepts in familiar situations	shows evidence of interpreting, applying and evaluating concepts in familiar as well as some new situations
Making informed decisions	needs assistance to distinguish between fact and opinion when making connections in social, environmental, economic and/or political contexts	needs some assistance to distinguish between fact and opinion when making connections in social, environmental, economic and/or political contexts	distinguishes between fact and opinion when making connections in social, environmental, political and/or economic contexts	distinguishes between fact and opinion and considers their merit when making connections in social, environmental, political and/or economic contexts
Perceptions and Influence of Science and Technology	needs assistance to identify and explain the factors that influence people's perceptions of science and technology in their daily lives identifies few instances of how science and technology are used in daily lives	identifies some factors that influence people's perceptions of science and technology in their daily lives identifies some instances of how science and technology are used in daily lives	identifies the factors that influence people's perceptions of science and technology in their daily lives identifies ways we use science and technology in daily lives	identifies and evaluates the factors that influence people's perceptions of science and technology in their daily lives identifies and evaluates the influence science and technology have on daily lives

Assessment for Science and Technology Achievement Project

Using Tools, Equipment and Materials Rubric

Criteria	Level 1	Level 2	Level 3	Level 4
Inquiry and design skills (including skills in the safe use of tools, equipment, and materials) ***MET (Page 13)***	*- uses tools, equipment, and materials correctly only with assistance;*	*uses tools, equipment, and materials correctly with some assistance;*	*uses tools, equipment, and materials correctly with only occasional assistance;*	*uses tools, equipment, and materials correctly with little or no assistance;*
Choosing and using tools and equipment	needs assistance to choose and accurately use appropriate tools and equipment in order to gather and analyze data or construct products	needs some assistance to choose and accurately use appropriate tools and equipment in order to gather and analyze data or construct products	chooses and uses appropriate tools and equipment accurately and with only minor errors in order to gather and analyze data or construct products	chooses and uses appropriate tools and technologies accurately and proficiently in order to gather and analyze data or construct products
Choosing and using materials	needs continuous assistance to choose appropriate materials and use them efficiently and effectively	needs some assistance to choose appropriate materials and use them efficiently and effectively	chooses appropriate materials and uses them efficiently and effectively requiring only occasional assistance	chooses appropriate materials and uses them efficiently and effectively
Caring for tools, materials and equipment	needs continuous assistance and supervision to follow appropriate and safe procedures for cleaning, maintaining and storing tools, materials and equipment being used	needs occasional reminders to follow appropriate and safe procedures for cleaning, maintaining and storing tools, materials and equipment being used	needs few reminders to follow appropriate and safe procedures for cleaning, maintaining and storing tools, materials and equipment being used	follows appropriate and safe procedures for cleaning, maintenance, and storage of tools, materials and equipment being used
Understanding safety considerations	does not follow safety considerations without constant supervision	follows some safety considerations but needs some supervision	follows most safety considerations but needs occasional supervision	follows all safety considerations without supervision

Appendix Three:
CANADA WIDE SCIENCE FAIR JUDGING SHEETS

Judge's Marking Sheet – Canada-Wide Science Fair

PART A: SCIENTIFIC THOUGHT – 45 %			Mark
Experiment An investigation undertaken to test a scientific hypothesis using experiments. Experimental variables, if identified, are controlled to some extent.	**Innovation** The development and evaluation of innovative devices, models or techniques or approaches in technology, engineering or computers (hardware or software).	**Study** A collection and analysis of data to reveal evidence of a fact or a situation of scientific interest. It could include a study of cause and affect relationships or theoretical investigations of scientific data.	
Level 1 (low) – Mark Range 5 to 15			
Duplication of a known experiment to confirm the hypothesis. The hypothesis is totally predictable.	Building models (devices) to duplicate existing technology.	Study of existing printed material related to the basic issue.	
Level 2 (fair) Mark Range 15 to 25			
Extend a known experiment through modification of procedures, data gathering, and application.	Make improvements to, or demonstrate new applications for existing technological systems or equipment and justify them.	Study of material collected through compilation of existing data and through personal observations. Display attempts to address a specific issue.	
Level 3 (good) Mark Range 25 to 35			
Devise and carry out an original experiment with controls. Variables identified. Some significant variables are controlled. Analysis such as graphs/simple statistics.	Design and build innovative technology or provide adaptations to existing technology that will have human benefit and/or economic applications.	Study based on observations and literary research illustrating various options for dealing with a relevant issue. Appropriate analysis (arithmetic, statistical, or graphical) of some significant variable(s).	
Level 4 (excellent) Mark Range 35 to 45			
Devise and carry out original experimental research which attempts to control or investigate most significant variables. Data analysis includes statistical analysis.	Integrate several technologies, inventions or designs and construct an innovative technological system that will have human and/or commercial benefit.	Study correlating information from a variety of significant sources which may illustrate cause and effect or original solutions to current problems through synthesis. Significant variable(s) are identified with in-depth statistical analysis of data.	

PART B: ORIGINAL CREATIVITY – 25%			
Level 1 (low) **Mark Range 5 to 10**	**Level 2 (fair)** **Mark Range 10 to 15**	**Level 3 (good)** **Mark Range 15 to 20**	**Level 4 (excellent)** **Mark Range 20 to 25**
Little imagination shown. Project design is simple with minimal student input. A textbook or magazine type project.	Some creativity shown in a project of fair to good design. Standard approach using common resources or equipment. Topic is a current or common one.	Imaginative project, Good use of available resources. Well thought out, above ordinary approach. Creativity in design and/or use of materials.	A highly original project or a novel approach. Shows resourcefulness, creativity in design. Use of equipment and/or construction of project.
Mark			

Paste Label here

PART C: DISPLAY
Maximum 20 Marks

1. Skill (Maximum 10)	**Max**	**Mark**
Necessary scientific skill shown.	3	
Exhibit was well constructed.	3	
Material prepared independently.	2	
Judge's discretion.	2	
2. Dramatic Value (Maximum 10)		
Layout logical and self-explanatory.	3	
Exhibit attractive.	3	
Clear logical enthusiastic presentation.	3	
Judge's discretion.	1	
Total Display Mark	**20**	

PART D: PROJECT SUMMARY
Maximum 10 Marks

1. Information	**Max**	**Mark**
Is all the required information provided?	3	
Is the information in the specified format?	1	
Is information presented clearly with continuity?	2	
Summary accurately reflects the project.	2	
2. Presentation		
Neatness, grammar, spelling in the report.	2	
Total Project Summary Mark	**10**	

Total Marks		
Part A: Scientific Thought (from page 1).	45	
Part B: Original Creativity (from page 1).	25	
Part C: Display.	20	
Part D: Project Summary.	10	
Total Mark awarded to this exhibit.	**100**	

FEEDBACK FOR THE EXHIBITOR(S)

Strengths _____

Recommendations _____

Judge's Name (Please Print!) **Judge's Signature**

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