Real Science & Technology:

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

Grade 1-6

(First Edition)

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"It is the supreme art of the teacher to awaken joy in creative expression and knowledge"
Albert Einstein

Introduction:

Children in the primary and junior grades have a natural wonder and curiosity about the world around them. By creating an engaging, enjoyable and exciting atmosphere in the classroom, and particularly in the science and technology curriculum area, primary and junior teachers are crucial in developing the skills and attitudes in their students that encourage and sustain this natural curiosity. Project-based science, in which children conduct authentic inquiries, allows students to construct new knowledge through the investigation of questions that arise every day in the classroom.

This document is designed to help teachers and administrators deliver an inquiry-based science and technology program that is an effective tool for the development of critical thinking skills, and for achieving expectations of the Ontario curriculum. It is a strategy to stimulate curiosity and involve children in authentic scientific inquiries, which will increase their understanding of how science and technology works in the real world. This, in turn, can help develop a life-long interest in 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

The first section in this document examines the benefits of doing project-based science. The second section describes ideas and strategies for incorporating project-based science and technology in classroom and school programs.

What is Project-Based Science and Technology?

Project-based science and technology is founded on the process of inquiry and incorporates a constructivist approach to teaching. This approach refers to the process where students conduct investigations that challenge their existing conceptions, and then use their discoveries, along with information and guidance from the teacher and others, to construct new knowledge and understanding.

Unfortunately, the word "project" in the science and technology context often conjures up an image of the competitive science fair project, completed at home with an excess of parental "help" (and stress). While science fair projects (preferably conducted at school) are valuable learning experiences, project-based science and technology can take many forms within an inquiry-oriented science and technology program. For older students, an **independent** project is essential to developing inquiry and design skills, which are an integral part of an effective science and technology program. However, it is not the only model. The methods by which project-based science and technology can be implemented range from whole class, teacher-guided inquiries in the primary grades to independent sci-tech projects at the junior level. Investigations can vary in length from a few minutes to several days or weeks, depending on the topic and independence of the students. Regardless of format, the purpose of project-based science is the development of inquiry and design skills, through activities carried out by students in a collaborative and supportive classroom.

Vineeth and Sajeevan are conducting an independent science project in grade 5, related to human organ systems. One of their guided inquiries during the unit looked at the function of the heart. The boys read books, manipulated a life-size human body model and viewed a video that explained how the heart functioned. The boys were also members of the Robotics Club and had a keen interest in using robotics to complete their project. They decided they would create a working model of a heart using their knowledge of robotics. While they could replicate the pumping action, they had difficulty getting the model to pump in a regular rhythm. They were also concerned that it didn't look right. After many trials, they decided to surround their unit with a plastic bag to simulate a pumping heart…

Rather than an "add-on" to the teaching of science and technology, project-based science and technology in the classroom has many benefits, which will be examined in greater detail in this section. They include:

- Managing the science and technology curriculum
- Developing inquiry and design skills in students
- Providing authentic learning and assessment opportunities
- Constructing knowledge and enduring understanding of science and technology
- Providing opportunities for curriculum integration

"If a single word had to be chosen to describe the goals of science educators during the 30-year period that began in the late 1950's, it would have to be INQUIRY."

DeBoer, 1991, p. 206

Project-based Science and Technology—Managing the Curriculum

The Ontario science and technology curriculum for grades 1-6 can be intimidating because of the number of expectations that appear in the Ministry document. Teachers may avoid science and technology projects because of time pressures and the perceived need to "cover" the content. A closer look, however, shows that independent or guided 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 curriculum. Teachers of younger students may be particularly concerned about the degree of independence students need to successfully complete projects; however, by starting with class-based inquiries, these skills can be developed. Project-based science can be an effective tool in primary and junior classrooms to get at the big ideas and develop inquiry and design skills fundamental to the understanding of science and technology.

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.

It is important to understand the extent to which project-based science meets 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 tends to revolve around the 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 scripted hands-on activities. Although textbooks can be an important part of a science unit and are useful for introducing basic scientific concepts, reliance on worksheets and textbooks may give teachers, administrators and parents the impression that the curriculum has been taught, when what really matters is whether it has been learned. An accumulation of notes and completed worksheets that focus on vocabulary and abstract concepts cannot develop or demonstrate understanding. In addition, 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."

It does not address the other two goals, which are:

"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

The Ontario Curriculum is also quite clear about the expected balance between the three goals:

> *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)

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

Thomas Huxley

A classroom program with an overemphasis on content tends to dwell on vocabulary, cloze activities (in the primary grades) and note taking (particularly in the junior grades) to convey large amounts of information in the mistaken belief that by being able to recall this information, the students "know" science. Such knowledge is usually fleeting and rote, and does not lead to enduring understanding. "Hands-on" activities can improve the learning environment, but only if they are well designed. Activities that follow an "experimental" procedure, but where the results are pre-determined, may be hands-on but are rarely "minds-on". Worse, these activities convey a sense that experimenting is like following a recipe, which couldn't be further from the truth. Considerable research shows that hands-on activities are not effective unless students are **active** constructors of their own knowledge and understanding throughout the process. A classroom program that regularly incorporates project-based activities is more likely to ensure that an appropriate balance of concepts, skills, and attitudes are developed. Students who really know science and technology are those who can successfully complete inquiry or design projects, independently or with the teacher's assistance, that address a question or problem that is relevant to them and develop enduring understanding of the concepts.

Start small: Although projects are usually thought of as an extended investigation, there is considerable value in shorter-term "projects" or challenges, particularly in the early stages of developing inquiry and design skills in primary grades. Technology challenges can be very effective. For example, students can be challenged to find the best sail design for a toy-sized boat. By testing and modifying designs through several trials, comparing results and refining the shape of their sail, students can learn much more about wind energy (as well as boats and sail design) than they would through the type of teacher-directed "experiment" where the results are pre-determined.

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 as part of the stability unit in grade 3 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 and leads to enduring understanding of science and technology concepts.

Recurring Inquiry and Design Expectations

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 and it is crucial that students are regularly presented with opportunities to practice these skills, beginning in grade 1. They are also the essential skills that students need to successfully complete an independent project. Projects are an effective and authentic way to assess these inquiry and design skills, as well as the content of a unit (see the section "**A project as a culminating activity**" for more details).

<u>Grades 1-6: Five Inquiry and Design Expectations Found in All Strands</u>

- Ask questions about and identify needs and problems related to…(ending depends on the specific strand content) Grades 1-3
- Formulate questions about and identify the needs… (ending depends on the specific strand content) Grades 4-6
- 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
- Record relevant observations, findings, and measurements, using written language, drawings, charts, and concrete materials (Grades 1-3)
- Compile data gathered through investigation in order to record and present results, using tally charts, tables, labelled graphs, and scatter plots produced by hand or with a computer (e.g., measure and record the motion of moving objects; manipulate computerized data collected from a moving object); (Grades 4-6)
- Communicate the procedures and results of investigations for specific purposes, using demonstrations, drawings, and oral and written descriptions

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. The overall expectations are what teachers are responsible for—the specific expectations are listed as **suggestions** to help achieve the overall expectations. Rather than attempting to cover every specific expectation, teachers should concentrate on the "big ideas" found in the overall expectations and use the specific expectations to help design their planning. When looked at in this way, the curriculum becomes more manageable and less daunting.

Projects are a viable way to cover the three overall expectations in a unit. Inquiry and design skills are inherent in a project. Project topics chosen from a specific unit of study can cover content from the unit, are linked to the real world and can address questions that are personally significant to the students. But more than a means to "cover" expectations, projects are a meaningful way to involve all students in constructing knowledge by tapping into their natural curiosity and wonder about the world around them, using their questions as a starting point for inquiry.

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

Mrs. Yu's grade 1/2 class was investigating materials and their uses. While completing a K-W-L (What I know, What I wonder, What I learned) chart with the class, one question that interested many students was how mittens keep you warm. As a class, they experimented with mittens on people and stuffed toys, used thermometers to record temperatures at time intervals, created a graph together and found that mittens trapped body heat and did not produce heat. Using re-sealing plastic bags, students then tested a variety of materials to discover the best insulator.

"Taking notes, conducting interviews or videotaping students engaged in a project (e.g., building a tower, creating their own musical instrument, designing a paper boat) provides teachers with an invaluable opportunity to assess the development of conceptual understanding and inquiry and design skills."

This grade 1/2 class discussed and applied concepts related to properties of materials in their project. They used inquiry and design skills to conduct their experiment, and data management skills (in the form of a line graph) to analyze their results. They also looked at the practical applications of various materials in real-world situations. Most importantly, the investigation was generated by the students' own questions arising from their observations and everyday experiences.

Authentic Learning and Assessment – Making Science and Technology Meaningful

Students, regardless of age, who are encouraged to pursue real science questions or solve genuine technological problems, are engaged in project-based science. Children actively construct meaning and are engaged in authentic learning when they are investigating questions that are personally meaningful. The questions may arise in science class, in other subject areas, or from activities and interests outside of school. This process parallels real scientific inquiry as students "become personally and directly involved in scientific investigation" (Andrea K. Balas, Eric Digest CSMEE, Jan. 1998, page 1). The possibilities for project-based science and technology are endless and only constrained by the student and teacher's imagination.

The example from the grade 1/2 class shows how real questions or technological problems offer authentic learning opportunities for students, and authentic assessment opportunities for teachers. Taking notes, conducting interviews or videotaping students engaged in a project (e.g., building a tower, creating their own musical instrument, designing a paper boat) provides teachers with an invaluable opportunity to assess the development of conceptual understanding and inquiry and design skills. Projects also provide for effective summative assessment of overall expectations - knowledge of concepts, inquiry and design skills, and the ability to relate science and technology to the world.

Projects as a Culminating Activity

Projects are a natural culminating activity in a balanced science and technology program. Just as a balanced literacy program is important to the development of reading, writing and oral/visual communication in primary and junior students, a balanced sci-tech program includes a variety of learning activities, such as purposeful readings, demonstrations, debates, videos, and experiments. Through focused investigations, students can be provoked into thinking about the big concepts and questions in a unit of study, deepening their enduring understanding, the evidence of true learning.

Mrs. Kenedy's grade 3 class had been investigating the growth of plants. A recurring question was, "What do plants need to grow?" Rather than giving the students the information, students were divided into groups and each group designed an experiment to test their ideas. With the teacher, the class created a student-generated rubric so that students would know what a "good" project looked like (See appendix 2). Some students put their plant in a cupboard. Some students did not water their plant. One group decided they would use a vacuum-sealing machine and encased their potted seed in plastic, removing most of the air. Each day the students recorded growth and drew labelled diagrams to record their observations. At the end of the experiment, the groups reunited to discuss their results and to share what they learned.

"The challenge for schools, they say, is to keep the thirst for understanding unquenched – not only for the duration of formal education, but for the span of a lifetime."

Lee Sherman. "Explore, Question, Ponder, and Imagine", Northwest Education: Living Lessons: How Projects Engage Kids and Deepen Understanding, 2001.

Throughout a unit of study, the new knowledge and skills that students develop should lead to further questions. How often are teachers presented with a "How come…? or "What if…?" question from a student? Such queries present several options, including a quick answer from the teacher (if he/she knows the answer), no answer, or an opportunity for further inquiry! At the end of a unit, the most relevant or important questions (to the unit, the students, or both) can be investigated as a culminating activity. Whether conducted as a whole class or as an independent activity, an effective culminating project empowers students to apply their newly developed conceptual knowledge and inquiry/design skills to a relevant question. The measure of meaningful learning is not whether a student can remember the answers to questions he/she's previously been asked, but whether he/she can ask and answer new questions about that topic.

In technological strands, such as "Structures and Mechanisms", the culminating activity could be a technology challenge, where students use their new skills and knowledge to solve a specific problem. As in the real world, the challenge may be very specific, but should give enough flexibility for students to develop creative and innovative solutions. The challenge can also provide opportunities for the integration of other areas of the curriculum.

Students in a grade 4 class were learning about medieval times in social studies, and pulleys and gears in science. The teacher saw the perfect opportunity to integrate these two subjects, as well as visual arts, with a design challenge. The class was read a scenario regarding a castle and a moat and asked to design a working drawbridge that would extend across a specific span. They were provided with a selection of materials to help with their construction and were guided through the process as they designed, researched and built their castles. Incorporating some time allocated to social studies and visual arts provided the students with an extended block of time in which to focus on the task. The teacher was able to work more closely with those students who required assistance while other students worked independently.

During a culminating activity, some students can work more independently, allowing the teacher to focus on those requiring assistance. Students working in pairs or groups parallels the work of real scientists and the resulting collaboration with peers, teachers and experts (if consulted), offers a forum for discussion of ideas and an opportunity for peer tutoring for ESL/ELD and exceptional students.

Quizzes, tests, labelled diagrams, drama presentations, questioning/interviews and writing assignments can be used as formative assessment during the unit to check basic understanding of key concepts, but an open-ended culminating project assesses deeper understanding and provides opportunities for students to demonstrate their scientific and technological understanding, skills, and higher order thinking.

Promoting an Accurate View of Science & Technology and Enduring Understanding

By the time many young people reach the junior grades they have suppressed their natural curiosity and enthusiasm, having received a clear message from school that knowledge of facts is more important than the thinking skills required for inquiry, experimentation and design. This message leads students (and many adults) to conclude that science is little more than a collection of facts, rather than a way of making sense of experiences. As a result, enduring understanding of science and technological concepts is elusive and rarely persists beyond the unit test.

"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.

Project-based science and technology promotes curiosity and inquisitiveness. By investigating questions that are genuine and interesting, students can be actively engaged and gain a more realistic and enduring understanding of the process of scientific inquiry. Understanding how science works 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 as adults to follow emerging controversies, think critically about issues, and form reasoned opinions about them. Students who have learned about weather and climatic patterns in a meaningful way in grade 5 will be begin to understand and examine the issues surrounding global warming and CO^2 emissions. Critical thinking skills developed through science and technology 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); however, this requires time. Students need time to ponder, debate and understand essential ideas, in order to grasp the concepts and skills. This type of learning cannot be rushed. Understanding of essential ideas is achieved through activities that combine the acquisition of knowledge with inquiry and design processes in a concrete and practical context. A hands-on (and minds-on) approach also provides a rewarding and engaging experience for students, increasing their enjoyment of science and technology, and increasing the likelihood of them continuing to take science and/or technology courses in high school and beyond.

"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 5 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! The "big ideas" that are crucial for the 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 or prepackaged science unit from cover to cover) is problematic. Pursuit of curriculum for its own sake obscures key ideas and does nothing to develop a deeper understanding in students. A grade 3 student may memorize and recite the different types of energy (gravitational, elastic, etc.), but will usually resort to his or her own understanding of energy to explain and understand everyday events. Children are active theory makers from the time they are very young, and come to school with many well-formed (though often unscientific) conceptions of how the world works. Teachers and students often suppress these "*alternative conceptions*", but research has shown that these understandings serve the student (and adult) well and are remarkably resistant to instruction.

Many grade 3 students will insist that if two different balls are dropped from the same height and at the same time, the larger ball will reach the ground first. A simple demonstration, with a teacher-provided explanation, might seem adequate to resolve the issue, but such an approach does not engage the student's understanding; it simply asks the student to believe the teacher instead of his/her own experience – precisely the opposite of what we should be trying to encourage. Inquiry and design activities, and projects specifically, encourage the student to put his/her own conceptions to the scientific test, setting the stage for him/her to construct a new and more scientific understanding. The extra time required to develop these deeper understandings necessitates that the focus remains primarily on key concepts or "big ideas."

"Concepts taught are not always concepts learned."

The teacher's role is to help the student integrate his/her everyday process of making meaning with the strategies of scientific thinking, logic, and knowledge of scientific principles. Projects provide an opportunity for students to look at questions or problems surrounding key concepts in science and technology, and construct new understandings about them. In other words, teachers have an opportunity to turn the "What if…", "How come…" and "Why" questions into genuine science inquiries. In reality, most primary/junior teachers feel vulnerable when answering questions in science and technology due to a lack of expertise. Rather than creating anxiety about answering student questions "correctly," project-based science frees the teacher from needing to be the custodian of "the right answers" and puts the responsibility for seeking answers where it belongs – with the student.

The role of dialogue in inquiry and design: The importance of "talk"

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. The transmission approach puts the teacher in the position of being responsible for student learning. For teachers without a science background, this often creates discomfort and apprehension about teaching the "wrong" way and it increases the likelihood of teaching scientifically incorrect information. 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. These strategies present a framework that more closely resembles the type of inquiry in which scientists engage and allows for student participation in constructing knowledge and understanding. 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.

Discussions and inquiries where the language of science and technology is used provide a meaningful context for the development of oral language 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. More importantly, discussions based on findings and questions generated by students involve and engage them in the process.

Curriculum Integration

James, a grade 4 student, has been spending the past week in his language class practicing procedural writing. In mathematics class, he looked at different methods of displaying data and what types of data are suitable for each of the methods. In addition, James has a slight hearing deficiency. He must, as a result, avoid headphones and loud noises. In science, they have been exploring sound energy and materials that reflect sound. His personal circumstances influence his project question: "Which materials best absorb sound?" so that he may consider which materials to choose in constructing a room. He uses what he has learned in mathematics and language to help complete his project. During the school's science celebration, James' language teacher assesses how well he has used procedural writing, followed by his math teacher, who assesses the data management strand.

"The important thing is not to stop questioning."

Albert Einstein

Project-based science and technology provides a rich opportunity for the integration and assessment of multiple curriculum strands. For primary teachers, science can provide the thematic context within which other curriculum expectations are addressed. Successful integration, particularly in the junior grades, often requires collaboration amongst teaching colleagues, as students often have more than one teacher for subjects such as mathematics, science, social studies, music, art and drama. Science and technology projects provide an excellent focus for teacher collaboration and participation in shared planning. Projects also provide an opportunity for extended, uninterrupted learning, where time in several subject areas is combined to permit more thorough investigations.

<u>Language</u>

"*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).

"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."

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

Integration of science with language is essential to developing scientific literacy. To complete a science and technology investigation, students must be able to incorporate many of the overall expectations outlined in reading and writing. In addition, oral language skills can be assessed during many phases of project work. For example, all grade 1 to 6 students are expected to communicate ideas for specific or a variety of purposes and, from grades 3 to 6, to specific audiences. All students must organize information, produce pieces of writing, revise their work and use and spell correctly vocabulary appropriate to their grade level.

"In order to become independent and fluent readers, students need to read frequently and to develop the skills used in reading for different purposes." (Ontario Curriculum, Grades 1-8, Language, page 27/28).

Introducing informational text, where information is visually supported and reading and understanding is explicitly taught within inquiry-based science and technology exploration, helps develop reading skills and motivates even the most reluctant student. Language expectations can be incorporated into project assessment rubrics, providing further opportunities for integration.

Literature is another effective springboard for developing questions and providing context for younger students that can lead to further investigation. One of the key skills in developing reading comprehension is learning to reflect on and understand what has been read. For example, a class discussion following a read aloud such as "Mirette on the High Wire" can generate questions and suggest experiments to investigate balance and centre of gravity.

Mathematics

Mathematics can easily be integrated with, and assessed through, science and technology projects. There are many topics in math that might apply to a project, but measurement and data management and probability will be found in most. Technology challenges often require that students plan and draw their design. This is an excellent opportunity to incorporate geometry expectations that require students to sketch two and three-dimensional figures and use measuring skills in a practical manner.

The Arts

When presenting a 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 and using symmetry to give their display a balanced feel. A technology challenge gives artistically inclined students an opportunity to add a creative flair to the design and presentation.

Specific science and technology strands in grades 3 and 4 (Light and Sound Energy and Materials that Transmit and Reflect Sound and Light) are a natural extension to music instruction. Dramatic presentations and role-play of scientific concepts (e.g., movement of molecules in the three states of matter in grade 5; push and pull of magnetic force, grade 3) provide opportunities for students to employ an alternate method of demonstrating learning. This is particularly effective for exceptional and ESL/ELD students whose reading and writing skills may be limited.

"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.

Social Studies

Many teachers find it challenging to teach two social studies and five science and technology units a year. Integrating topics helps manage time considerations and creates a more seamless school day. Technology challenges are a simple and logical way to link the study of science and social studies. In grades 3, 4, 5 and 6, the study of pioneers, medieval times, ancient civilizations and aboriginal people provide many possible scenarios from which to launch a technology challenge related to the Structures and Mechanisms strand.

In the primary grades, the characteristics and needs of living things and growth and changes in animals units, found the in the grades 1 and 2 curriculum, can be related to the social studies units examining the local community, how people meet their basic needs and how the environment influences their choices.

Physical Education and Health

Many expectations in the health curriculum can be addressed in science (and vice versa) through the Life Systems strand. For example, projects that examine how exercise and diet affect the structure, function and interrelationship of the human organ systems can be investigated as part of the study of Human Organ Systems in grade 5.

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, unconstrained by time or curricular expectations. In a co-curricular setting they are limited only by their skills and imagination. The teacher acts as an advisor or facilitator, giving students guidance, and making suggestions when appropriate.

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

Primary teachers play an important role in introducing the processes of inquiry and design. In the early primary grades, most children have a well-developed sense of curiosity, which teachers need to encourage and tap into to involve and engage their students. It is often best to begin by finding out what students know (or think they know) and help them articulate their questions about the world around them.

As a next step to developing these skills, teachers can guide the class through small inquiries throughout a unit and may, at times throughout the year, develop a class project based on the questions of the students. For example, in grade 1, students investigate the characteristics of objects and properties of materials and in grade 2 they study the properties of liquids and solids. Students in both grades are examining properties and phenomena through experimentation. Questions arising from their testing can be used to develop a class project that investigates one particular property of a variety of materials (e.g., Which material absorbs the most liquid?, Which materials sink or float in water?). These simple but authentic explorations prepare younger students for more independent inquiries in the future.

Before "unleashing" students to conduct independent science and technology projects in the junior grades, they need to be well prepared. Primary and junior teachers provide important teacher modelling and leadership. For example, teacher "think-alouds" model and develop appropriate questioning for students as they conduct an inquiry. A solid grounding in inquiry and design skills is required for successful independent investigations, but these skills are best developed through the primary and junior years. In planning a science and technology program that effectively addresses all three overall curricular goals, teachers will ensure that students develop 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

“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

Learning science and technology involves more than learning its content. It also involves learning how science and technology works. Classroom programs that are heavy on content convey the message that science is primarily a list of information. While facts are an important aspect of science, the process of how these "facts" are determined is equally important. In addition, there are misconceptions held by teachers, students and the public about how science works that interfere with the development of an authentic view of science and technology. In order to create an environment where students can be successful in conducting their own investigations and teachers are comfortable with the process, these misconceptions must be addressed:

- **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 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, an overemphasis on these types of activities offers little room for actual inquiry, and often generates little or no discussion. The unfortunate outcome of using these materials is that the students learn to look to the teacher for the "right" answers, and rely less on their own skills as active theory makers. As a result, it creates a very rigid classroom environment that often discourages risk taking, and defines the teacher as the expert. It is often the mistaken view of teachers that including these "hands-on" activities in their classroom constitutes good science. However, these activities lead to "verification rather than investigation" (Ebenezer and Connor, p. 36) and foster 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 challenged long-held views and new theories emerged. This understanding of science must be emphasized to encourage student inquiry. Otherwise, why bother with experimentation if the answer has already been determined!

"Purposeful play is an important part of theory making and a necessary component of inquiry-based science."

- **Misconception 2: Scientists (and teachers) have (or are expected to have) all the right answers.** Students (and teachers) often do not realize that scientists regularly come up with ideas, conclusions and theories that appear to be correct but, after further scrutiny and debate, turn out to be incorrect. The teaching of science and technology needs to acknowledge that scientists, like teachers and everyone else, are sometimes wrong, and often don't have answers to important questions. What is "right" in science results from a process of creative investigation, lively debate and general consensus. An effective science classroom mirrors this process. One of the greatest fears of grade 1 to 6 teachers, particularly those who are not science "experts", is that one day a student will ask a question to which the teacher will not have an answer. However, there is no master book of answers—if there was, there'd be no need for science and technology at all! Having Trevor or Ralisha ask a question for which you don't have a ready answer is an excellent opportunity to shift the onus from the teacher to the student: "That's an interesting question! What can we (or you) do to investigate that question?"

- **Misconception 3: There is no room (or time) for play in science**. A young child in a high chair knows that if a spoon is knocked from the tray, it falls to the floor and someone will pick it up. It doesn't take long before the child formulates a personal scientific theory – dropped things fall down. Give a child who has established this personal theory a helium balloon and they are fascinated. Once they let go, they discover that not all objects fall to the ground! Even more intriguing is to ask the child to explain this strange behaviour. The explanation is unlikely to involve abstract scientific concepts like density or buoyancy (nor should it), but it will provide insight into how the child explains what he/she sees every day. 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).

Children arrive at school as active theory makers. Activities where students are utilizing their natural inquisitiveness to actively build and construct knowledge, and testing theories and modifying them as necessary, give an authentic view of how science and theory-making occur in the real world. Purposeful play is an important part of theory making and a necessary component of inquiry-based science. Handing out batteries, bulbs and wires to grade 6 students may provide an opportunity for them to explore. However, effective challenges and follow-up (rather than step-by-step exercises) are what transforms the activity from aimless play to a meaningful learning activity for students, where they discuss, build and test theories on electrical circuits. Introducing discrepant events – things not easily explained, such as the helium balloon - is also an effective strategy for challenging beliefs, generating questions and encouraging theory building in students.

"Following a carefully scripted procedure, where the teacher places a painful emphasis on recording and reporting is not genuine. "Real" science tends to be much messier."

In a grade 5 class, students have been investigating the properties of matter. Following a reading of the story Oobleck by Dr. Seuss, students were given a green substance in a container, dubbed Oobleck (cornstarch, water, and green food colouring). They were then asked to investigate and classify the substance – was it a solid, liquid or gas? After 20 minutes, and much discussion, students wanted to challenge the definitions of solids, liquids and gases! They concluded that their substance acted, depending on how it was handled, like a solid or a liquid and were able to use their knowledge of the properties of matter to write their "proof."

- **Misconception 4: Science is all about the "scientific method".** The "scientific method" is a useful and standardized framework in which experimental results are reported, but it is rarely how science is conducted in the real world. 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. "Real" science tends to be much messier. Students must certainly be taught experimental design, observational skills, the value of controls and recording results, and other skills needed to make their experiments valid. However, real inquiry in science and technology is a "messy" process full of dead-ends and multiple attempts on the way to constructing an understanding. It is not "a collection of prepackaged, hour-long (or less), hands-on activities that are often disconnected from each other." (Moscovici and Nelson, Science and Children, January 1998, p. 14). Students and teachers need to appreciate 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.

Learning to generate questions & design problems

By the time students reach the junior grades, they should begin to take responsibility for the design and completion of an independent project. Primary teachers can begin this process by modelling a format for questions that can be investigated. 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 experiments and investigations. For example, in the grade 2 energy unit students could investigate the question "How does the size of the blade affect how fast my pinwheel will rotate in the wind?" Students can conduct the inquiry, and as a follow-up, they can be challenged to use their knowledge of wind as a source of energy to help them explain WHY they got their results. Once students are familiar with this question framework they will be well-equipped to develop and investigate questions of their own.

"Posting students' questions throughout the classroom reinforces the impression that students have ownership over their own learning and are constructing their own knowledge."

Primary and junior teachers often find that the use of scientific vocabulary, such as dependent and independent variable, is confusing and daunting. While it is rarely necessary (or helpful) to introduce students to such terminology at this level, questions in this format clearly establish a framework for teachers and students that explains what these terms mean.

How does (independent variable) affect (dependent variable)?
How does the type of soil affect the rate of plant growth?
How does angle of a ramp affect the distance a toy car will travel?

Using this question format, students in the late junior grades can begin to use these terms accurately.

Helping students find ideas

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

i) **Encourage students to question! Science topics are everywhere.** Young students come to school prepared to ask questions. As teachers, we need to stimulate that sense of wonder and curiosity. Students often come up with interesting questions during activities, discussions and readings. These can be recorded on cards or chart paper and posted in the room. Posting students' questions throughout the classroom reinforces that students have ownership of their learning and are constructing their own knowledge. Valuing student input also fosters an atmosphere of inquiry and excitement. Student questions activate prior learning, serve as guideposts for investigations, and provide enrichment opportunities for students who require further challenges. Later, students can review these questions for project ideas, especially if the project serves as a culminating activity.

ii) **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. Starting with what students know, units of study can begin with a K-W-L chart (What I know, What I want to know and What I learned). For primary students, a K-W-L chart can be posted in class and added to throughout the unit. For the junior grades, students could have a page at the front or back of their notebook where they record questions that come to mind over the course of the unit. 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 and facilitates the connection between science and technology and the real world.

iii) **Give students enough time!** In grades 1 and 2, investigate student-generated questions as a class project. Shared reading and analyzing informational texts are key reading strategies that can be incorporated into science and technology inquiries and allow for uninterrupted blocks of time for students to carry out explorations.

As early as grade 3, students can begin independent projects. 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 look for personally significant questions throughout the unit. Try to work towards a school science celebration to generate excitement with the students and the community. Work with your students to develop a timetable and help students stay on track. Plan with the teacher-librarian, ESL and Special Education teachers to provide support for all students. Offer sufficient time and support (library and computer access, classroom textbooks and materials) to assist students in the inquiry process.

iv) **Teach students to read critically, and to question what they read.** Exposure to textbooks or informational text in the primary/junior grades is a necessary part of a balanced literacy program. New strategies are necessary to read and understand this form of writing. As textbooks are often written at the instructional level (or above), read aloud and shared/paired readings are appropriate strategies, even in the junior grades. As part of a balanced science and technology program, these readings can generate discussion and questions that drive the process of inquiry. Students who are engaged and encouraged can take the simplest activity or paragraph from what they have read and come up with dozens of questions individually, in small groups, and as a class.

v) **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. Use class trips or visiting experts to generate following-up investigations.

Scientists in School came to a grade 4 class for a presentation on food chains. Groups of students investigated the favourite food of dragonfly nymphs. Students fed their nymphs, made observations and presented their results in a class-designed histogram. The results were then compared with another grade 4 class that had the same presentation. As a *follow-up, some of the students wanted to share this information at the upcoming school Science Celebration. A number of students took responsibility for researching dragonflies and designing the project. As a result, they created a project entitled, "What's For Dinner?" They used procedural writing, researching skills, data management and visual art in a collaborative, independent and successful project.*

vi) **Use technological challenges to launch an investigation.** It is a good idea to encourage students to look for a specific, but open-ended problem to solve for technology projects. 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.

When Samantha's mother returned to work, she had to eat lunch at school. She liked to have a hot lunch and was disappointed to find out that she did not have access to a microwave at lunch. At the same time, her class was studying matter and materials. As a culminating activity, Samantha suggested that they create the ultimate lunch box, one in which food could be kept hot or cold. An evaluation of science and art expectations was incorporated in the student/teacher-designed rubric used to assess this project.

"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.

Displaying a Project

Completing a class project in the primary grades provides the teacher with an opportunity to model how an attractive and logical display can have an impact on how the project is perceived. This modelling prepares students for independent projects in future grades. For students in the junior grades, providing an outline or saving samples from previous years provides exemplars for students to follow.

Some ideas for students to consider when planning a display include:

i) Think of a catchy title that is relevant and clever to 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 or technology project.
iv) Use photos or diagrams to show steps of the design process, and to display results.
v) Have clearly labelled sections that show the focus question or design problem, concepts, procedure, results, answers to the focus question, and applications.
vi) Check for accurate grammar, spelling, punctuation, and neatness. These are important, especially for a public audience.

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

"Expectations need to be outlined at the outset, clearly defining the role of parents in the process."

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 a 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 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/ELD 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/ELD students and take place in a non-threatening, natural atmosphere. Collaborative work is the perfect setting for students to use and practice English.

Depending on the Stage of language proficiency, ESL/ELD 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). Sample adaptations and modifications for selected science units are also included (Grade 2 Movement and Grade 5 Weather).

Whose Project Is It? Positive Parent involvement

One concern often raised about projects is based on the classic image of the parent who obsessively or begrudgingly slaves away to complete a child's science project. This concern is legitimate, and must be addressed.

To successfully build independent design and inquiry skills, it is important to involve parents early in the process, 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 for ideas, as students try to make meaning out of 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. Expectations can be outlined at the outset, clearly defining the role of parents in the process. 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 on the project's progress.

A series of brief discussions with a student will quickly reveal his/her involvement in and understanding of the project and some type of interview/conference should be included in the final assessment. 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. In a school-wide celebration, it is vital that the excellence of student work (and not the work of parents) is recognized and celebrated. Ultimately, the goal of project-based science is to develop critical thinking in students and it is an objective that should not be lost through the efforts of parents. For most students, the ideal circumstance for project-based science and technology is with the assistance and support of peers and teachers. Assessment of the process, as much as the product, is essential in evaluating student understanding.

What Makes a Great Project?

Queenie, a grade 5 student, was a recent immigrant to Canada. While she still maintained a diet more in keeping with life in China, she and her parents had started to incorporate more Canadian foods into their diet, particularly as they lived close to a fruit and vegetable stand that sold local produce. Queenie noticed that when she ate corn, her bowel movements included undigested corn. When she began to study the human organ systems and their function, she decided to find out exactly how long it took to digest a meal. She and her three group members decided to use corn as the mechanism to time how long it took to digest food. They each ate corn with a meal, graphed the results and used the average of the times to predict digestion times. In their conclusion, they asked the question, "How would this compare to the results in adults?" as a further area for investigation.

Queenie'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 interesting question or problem from which to begin.

A Project in Stages

The completion of a whole class project is an effective strategy for developing inquiry and design skills in primary students, preparing them for future independent projects. For most students, designing and conducting an independent project can be an organizational challenge. Breaking it into manageable sections and providing feedback at each of the stages is invaluable. For primary students, working together and modelling each stage of the project helps ensure that the process becomes familiar. To ensure that students in the junior grades remain headed in the right direction, they can be given a timeline to be signed by the teacher, student and parent as each stage of the project is successfully completed. This process helps the teacher monitor the progress of each student, measure the amount of student effort and input and identify students who are experiencing difficulty earlier rather than later. 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 (in other words, a plan);
- collecting and displaying data, results or recording the design process (graphs, procedures, observations);
- analysis of the findings or testing of the design (conclusions); and,
- future applications and implications of the work (application of science and technology to the real world).

"Bear in mind the underlying principles of the project approach: Skills applied to meaningful activities are more likely to be mastered"

Katz and Chard

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 Appendix Two, 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. To provide an effective reminder for students, post the rubric on chart paper in the class, as well as providing individual copies when the project is assigned.

If 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 combine skills of inquiry and design, expectations about relating science and technology to the world, as well as specific content from the unit. Designing the rubric with the students gives them a better idea of what a "good" project should look like and gives them input into the project's assessment.

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 and the ability to modify the language to make it understandable for students.

Projects done as co-curricular projects can be assessed using the rubric from the Canada Wide Science Fair (see Appendix Three). This is an effective way to introduce grade 6 students to the competitive aspect of science and technology projects in grade 7-12.

Where can great projects go?

School or Classroom Science and Technology Celebration

The vast majority of projects will not go beyond the classroom or school. That's OK! Science projects are intrinsically rewarding, and displaying them for the class or school can and should be a positive experience. During winter or spring music concerts, Education Week or any other after-school activity, students can proudly showcase what they have learned in science and technology. A school-wide science and technology celebration can be held jointly with parent interview nights, providing another way to include the school community and recognize student excellence.

Regional Science & Technology Fairs

Across Ontario, there are about 30 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. While students in grades 1-6 will not be judged at most fairs, it is an opportunity to expose the younger students to the Science and Technology Fair and generate future interest. A listing of regional fairs is available at the Sci-Tech Ontario website: www.scitechontario.org.

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. One example:

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/

Real Science: 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 helps them to connect science and technology to each other and the outside world. The strategy encourages and exploits the natural curiosity of students to create knowledge, understanding and, above all, scientific literacy. Through authentic investigations, students develop an accurate understanding of how science works, and critical thinking skills that will serve them well in their future endeavours. Inquiry-based science and technology projects trigger higher order thinking skills and provide "Level 4" opportunities for all students. Important connections exist among 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.
- Project-based science and technology incorporates constructivist learning, and encourages students to explore the important questions and concepts related to a topic.
- Inquiry and design skills needed to complete a project are found in the expectations for every unit of the Ontario science and technology curriculum.
- Projects are an effective culminating assessment activity for a unit.
- Project-based science and technology can be used to integrate knowledge and skills from many different curriculum subjects.
- Project-based science and technology creates a collaborative atmosphere, that relieves teachers from their perceived role as "source of all the answers"
- Common misconceptions about science and technology can hinder effective science and technology instruction and independent project work.
- How does _________ affect __________? is an effective framework for generating inquiry and project questions.
- Students can complete a project in stages, breaking it down to manageable pieces.
- 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.
- There are many exciting opportunities for students involved in project-based science and technology.

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Appendix One:
STUDENT HANDOUTS

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

Throughout our unit of study, we have asked and answered some of our questions related to ______________. Many of these are posted around the room or are in your science duotang/notebook. Some of you already have a definite question that you want to investigate. However, others are still looking for an interesting question. Here are some suggestions to help you find a topic.

1) Begin with Your Own Interests

Many of you are athletes, artists, musicians, mathematicians and budding writers. Some of you are interested in history, geography and of course, science. Others like building or creating objects or inventions. In the space below, list 4 or 5 general areas of interest for you to help generate a topic:

____

____

____

____

2) Research/Investigate the Topic

From your list of interest, choose one topic that you think might lead to an interesting science inquiry. Then use classroom resources, the school and public library, CD-ROMs or the internet to develop a specific question about the topic. In the space below, list your resources used and the specific page numbers to include in your bibliography (use the sample bibliography in your writing folder). Two resources are the minimum you should use.

____

____

____

____

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

A good focus questions is specific and clear, and avoids having YES or NO for an answer. Use the question format developed in class:

How does ____________________ affect the

________________ of ____________________ ?

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

How does the <u>amount of baking powder</u> affect the <u>density and height</u> of a <u>pancake</u>?

A good question is a question that can be answered! In the example, you can probably think of a method or experimental process that could be used to help answer the question.

A good question also tells us what NOT to do. In the above question, you would not alter the amount of any other ingredient in the recipe. Although it might be interesting to try this AFTER you have conducted your tests, this question only addresses the effect of baking power.

Take your time in developing your question. Talk it over with friends, family and of course, your teacher. You may have to edit your question many times before you get what you want. You do not have to use the question format shown above, but it is an effective way to develop many interesting questions. Good luck!

Your focus question is due on

____

?

Science and Technology Projects
PROJECT TIMELINE

Group Members: ______________________________

____

____

Class time will be provided to complete your project. You will be expected to design and carry out an experiment to answer one of the class questions about _________________ (or generate one of your own).

Our group will be investigating: (state the question or problem)

____

____

____

____

Topic Approval (Teacher's signature)

____

Materials we need:

____

____

____

Responsibilities of each group member:

____

____

____

First deadline (Experiment plan):

____

Second deadline: (Data collection):

____

Final deadline (Display of results and application to real world):

____

Congratulations!

Science and Technology Projects

CHECKLIST FOR SCIENCE AND TECHNOLOGY REPORTS (JUNIOR)

TITLE/TOPIC

- ❐ A colourful, clear, catchy and neat title related to the focus question or technology challenge.

INTRODUCTION

- ❐ Written in paragraphs
- ❐ Question or problem is stated.
- ❐ Predictions, with reasons (hypothesis) are mentioned.
- ❐ Summary of how you will investigate your question.

MATERIALS AND METHODS

- ❐ All materials are listed.
- ❐ Procedural writing used to outline method.
- ❐ All tests and measurements are repeated a number of times.
- ❐ Diagrams, pictures or sketches of methods are displayed.

OBSERVATIONS AND RESULTS

- ❐ All observations and results are reported.
- ❐ Information is organized into charts, tables and/or graphs.
- ❐ Calculations which are necessary are shown (show your work).

DISCUSSION/CONCLUSION

- ❐ Written in paragraphs
- ❐ Questions or problem is restated.
- ❐ Results are given.
- ❐ Conclusion of results and how they relate to predictions.
- ❐ Possible application of conclusions.
- ❐ Any questions generated for further investigation.

GENERAL LAYOUT

- ❐ Each subheading numbered and headings underlined
- ❐ Neat writing, printing or typed
- ❐ Paragraphs indented
- ❐ Proofread for spelling and sentence errors
- ❐ Colourful illustrations with printed labels
- ❐ Enhancements included (illustrations, graphs/charts)
- ❐ Bibliography included (at least 2 books)

OTHER

- ❐ All rough work included
- ❐ Much time and effort put into project
- ❐ Checklist completed and included with project

Final deadline:

Science and Technology Projects
HOW TO DISPLAY YOUR PROJECT

In order to have the greatest impact with your project, you must seriously consider your audience. An effective project is:

- Attractive
- Logically organized
- Eye-catching
- Neat
- Clearly outlines the experimental process

Use the following check-list to help you assess whether your project fulfills these expectations.

- ❐ A catchy title and pictures or drawings that are relevant and clever and can grab people's attention
- ❐ Use appropriate graphs to visually display data and show trends in the results
- ❐ Display equipment used in the experiment or technology project creations
- ❐ Use photos to show steps of your design process, and to display results
- ❐ Have clearly labelled sections that show your focus question or design problem, concepts, procedure, results, answers to the focus question, and applications
- ❐ Use complimentary or contrasting colours for the titles and backboard (check from a distance to make sure they can be read)
- ❐ Accurate grammar, spelling, punctuation, and neatness are very important

When you are close to completing your project, have a friend, an older sibling or parent take a look at your project. Sometimes having fresh look at your project can help point out areas that need improving. Above all, be creative and have fun with your project.

Appendix Two:
SAMPLE GRADE 3 STUDENT-GENERATED RUBRIC

Sample Student-Generated Rubric

<u>Grade 3- Growth and Changes in Plants</u>: Using the expectations listed below, the teacher developed a rubric with the students. The rubric, along with the expectations, was posted in the classroom to help guide students through their investigations. Because it is in simple, child-friendly language, students were quickly able to identify what a "good" project looked liked.

- design and conduct a hands-on inquiry into seed germination or plant growth;
- ask questions about and identify some needs of plants, and explore possible answers to these questions and ways of meeting these needs (e.g., predict how long a particular plant could go without water before its leaves started to droop);
- plan investigations to answer some of these questions or find ways of meeting these needs, and explain the steps involved;
- use appropriate vocabulary in describing their investigations, explorations, and observations (e.g., stem, pistil, stamen, flower);
- record relevant observations, findings, and measurements, using written language, drawings, charts, and graphs (e.g., produce a series of drawings to show a plant at different stages of development);
- communicate the procedures and results of investigations for specific purposes and to specific audiences, using drawings, demonstrations, simple media works, and oral and written descriptions (e.g., make a graph that shows the number and kinds of trees found in different yards; design and construct a terrarium or garden that reproduces the conditions that they found to be requirements of specific plants).

Expectation	Level 1	Level 2	Level 3	Level 4
Knowing	• almost no descriptive words • meanings of words not explained	• few descriptive words • few meanings	• uses some descriptive words, with some meanings	• uses accurate, descriptive words, and includes meanings
Doing	• no diagrams • unsafe behaviour during experiment	• fewer than 2 diagrams • safety practices usually observed	• some diagrams illustrating observations • usually follows safety rules	• uses diagrams to show observations • always follows safety rules
Applying	• real life example missing	• real life example, no reference to information learned in expt.	• real life example, with reference to information from expt.	• real life example gives application of concepts from expt.

Appendix Three:
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

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;

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;

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

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 Four:
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			

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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 ______________________________

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Recommendations ______________________________

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

Use this form to give a mark to each exhibit, and to assist you in ranking the exhibits assigned to you. This mark will not be used in subsequent rounds of judging. **Return this form to the Chair of your Judging Team.**

NOTES

NOTES

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