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Introduction

Project-based Learning

Australian educators are being required to place more emphasis on science, technology, engineering and maths (STEM) to ensure that today's students will be prepared for their future careers. Additionally, it is important that children learn and practise the 21st-century skills of collaboration, critical thinking, problem-solving and digital literacy in their daily curricula. These collaborative skills are imperative for students to learn, but they are not without challenges. *Stepping into STEM: Year 5* provides students with needed practice in these areas.

Project-based learning, simply put, is learning by doing. Project-based learning, or PBL, tends to be deeper learning that is more relevant to students, and thus it is remembered longer. We need to educate students to be global competitors; and to do so, we must help them to think creatively, take risks and put what they are learning into practice. After all, it doesn't do much good to know a formula if you don't know when to use it. Students also need to learn the value of failure as a learning experience. Some of the ideas and efforts they will make during an activity will not work. This can turn into a very positive experience since knowing what won't work, and why, may lead to the discovery of what will work!

Reading informational material provides needed background, but *doing* makes the difference. Concepts, ideas and experiences of hands-on activities remain lodged in the brain for retrieval when needed.

In STEM curriculum, project-based learning is a must! Its collaborative style guarantees that 21st-century skills are fully integrated into the curriculum while supporting students' academic and socio-emotional growth. Furthermore, PBL allows teachers to assess what students comprehend immediately and adapt curriculum accordingly. Most of the activities in this book require more than just one person in order to successfully achieve the objectives.

Connecting Science, Technology, Engineering and Maths

STEM activities blend four essential and related learning experiences into one activity. The science project provides the platform for engineering design experiences in virtually every activity. For example, a science activity dealing with the motion of a pendulum involves learning elements of engineering design to achieve the best results. Technology – both simple and high-tech – provides the framework and recording information. Some of the technology is related to the materials and techniques used in constructing the pendulum; computers are effective in recording and comparing results. The maths element will involve comparisons expressed in decimals, fractions, ratios and percentages, as well as measurements, graphs, charts and other visual representations.

The Need for Interaction and Collaboration

Today's scientists share ideas, experiences and experiments with colleagues as close as their own university, as well as at great distances across the globe.

Student scientists, like professional scientists, need experience working with partners in a collaborative and supportive environment. They need to exchange ideas, test theories, perform experiments, modify their experiments, try novel approaches – even those that may not appear useful or serious – and cooperate with each other in all aspects of the project as they seek to accomplish their objectives. This process is often referred to as "The Design Process". The Design Process mini poster on the next page can be posted or copied for each student.

A basic requirement of this collaborative effort is a willingness to seriously consider all suggestions from the members of the team. Ideas should be considered, tried, tested and compared for use in the project. Students should work together to select the most efficient and practical ideas and then methodically test each one for its useful application in the activity.

Growing Critical Thinkers

While all members of a team need to be respected and heard, members of the team also need to critically examine each idea to see if it is feasible. Students need to apply their learned experiences in these activities, and their serious attention should be given to testing each idea for feasibility and practicality. Students can develop this skill by considering each serious suggestion, testing it for workability and then determining its value. Students need to examine the available materials, work with them in an organised way, record their results and compare these results.

Critical thinkers are organised and methodical in their testing. They examine the ideas generated in the free flow of comments and discussions. Critical thinkers determine which ideas can be tested and then carefully compared for useful application to the problem they are trying to solve. They keep an open mind. Critical thinkers base their judgements on observations and proven outcomes. Critical thinkers aren't negative, but they are sceptical until they observe the results of an activity.

One of the hallmarks of a scientist is to ask questions. Another is the effort to seek answers through effective investigations, tests and experiments. You want to encourage your student scientists to practise critical thinking by asking thoughtful questions using academic vocabulary, and developing creative ways to test possible solutions.

"Show me."

"Let's check it out."

"How can we test it to see if it works?"

The Four *I*s: Inquire • Investigate • Interact • Invent

The four basic elements of an effective science or STEM activity can be categorised as Inquiry, Investigation, Interaction and Invention.

1. Inquiry is the process of determining what you wish to learn about a scientific or natural phenomenon. It can be as simple as watching a student's swing move back and forth, observing a schoolyard game of marbles or sucking on a straw. Some of the same principles of science may apply to a helicopter rescue of a swimmer, a batted ball in a cricket match or the process of getting water out of a ditch. The questions are always the same:

"Why did it happen? Will it happen every time? What happens if … you change the length of the swing, the size of the marble, the diameter of the straw, the weight of the swimmer, the diameter of the ball or the size of the siphon hose in the ditch?"

In the simplest form, **Inquire** is a question: Why … ? What if … ? How … ?

2. Investigation is the action a scientist takes to learn more about the question. It involves the process a student scientist needs to follow. The investigation can involve background research, the process of doing an experiment and the interpretation of the results. Reading a science text about the workings of the pendulum is not the same as actually constructing a working pendulum, adjusting it to different lengths and weights, and carefully observing its features and behaviour in varying circumstances. Measuring these in mathematical terms provides the opportunity for valid comparisons as well.

3. Interaction requires student scientists to work with one or more classmates to assess the problem or question, determine the nature of the investigation and analyse the results, looking for the most reasonable or useful course of action. Most detailed scientific experiments require more than two hands and benefit from the shared input of two or more actively involved minds.

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The Four *Is* (cont.)

From a practical point of view, experiments done with students are more effective with teams of two. In larger groups, one or more team members often feel left out, don't get to actually do the hands-on construction and often end up in distracting behaviours. Teams of two require the active involvement of both individuals in all phases of the activity all the time. An off-task student in a team can be refocused by a partner or the teacher.

It is important to have enough materials and equipment for the basic activity for each team. The materials used in the activities in this book are inexpensive and easily available to facilitate two-person teams.

4. Invention is the final stage of the 4 "*Is*" in which the science activity involves the effort to create or invent a solution, modification or improvement. This can be the most challenging aspect of the activity. Suggestions, at first, tend to be far out, impractical, silly or impossible to do with the available materials. The most effective teams discuss possible solutions and then start manipulating the materials as a form of "thinking with their hands".

The invention aspect of the activity is nearly always the final step of the activity. For instance, after multiple sessions manipulating and measuring results with a pendulum, students should have enough background and hands-on experience to invent an application for this tool. It may be a toy swing for a doll, a time-keeping mechanism for a class activity such as a timed maths exercise or an attempt to make a perpetual-motion machine (or one that just lasts longer than anybody else's).

1 Inquire

2 Investigate

3 Interact

4 Invent

The Need for Journalling

Scientists keep records. They are meticulous in recording the results of their investigations and often refer back to investigations done in previous months and years. They use this information as needed for further investigations, related experiments and in publishing their work.

Ideally, all science students should keep a journal recording the investigations they have been working on. With continued practice, students will develop the habit of journalling after each period of investigation. It is helpful to use three-ring folders for the students' pages from this book, including the journal entries. It is easier for students to keep information in one place and to refer back to previous investigations for discussion purposes and records. Daily spiral notebooks, composition books or three-ring folders can also be used.

It is suggested that a separate entry be made for each investigation session. Have students enter the date and investigation title or stage on each new entry. Include the key question for each activity. This is the starting point for each investigation. As students proceed through each unit, they should record – using adequate details – the process and materials used to investigate the question. Encourage students to use appropriate vocabulary when journalling.

The variations in technique, the engineering adjustments, the technology employed and the results of each modification should be recorded. The mathematical applications should also be noted. If the length of the pendulum fishing line was doubled or cut in half, this is critical information. If the weight was doubled from 8 grams to 16 grams, this should be noted, and the effect on the pendulum's swing distance and duration should be recorded. The results of each trial should be briefly recorded.

The most important information in the journal should be the conclusions of the research team about the answer to the testable questions the team was investigating. Individual researchers may draw separate conclusions about these questions, but the conclusions need to be based on objective facts and recorded information.

The Design Process Review

The journal entries should be the "notes" student scientists use when sharing their information during the class discussion called "The Design Process Review". The teacher should act as the moderator of this discussion and ensure that all students get an opportunity to share their experiences, results and scientific observations. These discussions work well as a 10-minute closure activity at the end of each period.

Encourage all students to take turns sharing the results of their activities and the conclusions they drew from their experiments. Data summaries may include photos, videos or other relevant materials.

Model and encourage serious reporting. Encourage students to incorporate new vocabulary into their discussions, their journalling and their presentation pieces.

The writing (journalling) and the review are vital elements in the design process. They provide students with the opportunity to share their experiences, and they serve as an excellent part of the assessment process. It is suggested that you allow at least 15 to 20 minutes to complete these activities.

You may choose to act as a moderator. You can allow students to share as teams or individuals about each activity and others they have done on related subjects. You may also use smaller groups with student moderators.

Keeping Things in Perspective!

A STEM class will rarely be perfectly quiet! In fact, the low buzz of purposeful conversation is an indicator that students are actively engaged. The teacher serves as the facilitator, providing guidance, crucial information and directions at the outset. It is important to regularly check on each group to offer encouragement, advice, correction and support.

Teachers need to evaluate how students are doing as teams proceed with investigations. In addition to guiding the learning process, it is also very important to draw closure on the activity by moderating the final portion of the Design Process Review where you draw conclusions and highlight the core learning concepts embedded in the activity.

Unsuccessful periods happen in any class, no matter how capable the instructor or how gifted the students. Things can go wrong, bells ring forever, announcements break the flow of instruction and construction, and all the other distractions of school life can occur. You may get a true scientific discussion going, only to have it go off into areas unrelated to the thrust of the investigation.

But there are also those times when you encounter the pleasant experience of no-one paying any attention to the distraction. A visitor or principal enters the room, observes the activity for a moment and either leaves or joins a group. The science discussion reverts to the main idea and goes smoothly or vigorously along, driven by students who are focused and on task. Yes, it happens!

Students can really "get into" science. They enjoy the openness involved in the activity, the collegial nature of working on a project, the materials they get to manipulate and the mental stimulation of solving a problem or creating a better product. A good, productive, stimulating science lesson can make their day – and yours, too.

How to Use This Book

Stepping into STEM is arranged with flexibility in mind. One method is to move from lesson to lesson in each unit and proceed through the units in order. But the number and order of units completed throughout the year is completely dependent on classroom and curriculum needs. You may want to choose the activities with which you are more familiar or those that fit your school schedule better. *Stepping into STEM: Year 5* contains, in total, seven units. The organisation of each unit moves from a teacher-directed initial activity, through two or three more open-ended activities, to a final challenge activity that allows students to create their own unique "invention". The final unit in the book is longer and more complicated in scope and involves a culminating activity that challenges student minds and helps draw closure. The units require students to incorporate a range of science, technology, engineering and mathematics concepts into their learning. Each unit introduces and defines new concepts and terminology in a vocabulary list. Some of these terms may be new to students – spend time working through the lists with students and have the lists close to hand for quick-reference during each activity.

The units in *Stepping into STEM: Year 5* explore the following concepts:

- Electric Circuits: conductors, circuits, currents, electrons
- Air and Water: liquid, gas, atoms, molecules, evaporation
- Reflection and Refraction: angle of reflection, angle of incidence, angles, refraction
- Water Pressure and Capillary: water pressure, atmosphere, capillary action, surface tension
- Magnetism and Electromagnetism: magnetic poles, attraction, electromagnetism, induction, distance
- Working with Motors: negative, positive, gravity, angles
- Building Bridges: tension, load weight, design, angles, triangles, measurement

Pacing Units and Lessons

Planning the length of time for completion of each unit can be flexible. You may choose some or all of the units and pace them throughout the year, building each unit into your science curriculum. You may find a unit compliments other aspects of your curriculum effectively and wish to use only that unit's activities to elaborate on students' existing knowledge. You might also consider using the simpler activities in a unit in one term and extending students' learning by using the Challenge activities, which are more difficult, in the following term. Be mindful of unit supplies; many units reuse materials used or student-built inventions in later activities. Later activities in the unit may use something made in an earlier activity. Hold on to any inventions or creations for subsequent use. If a unit topic fits in well with what is currently being taught, embed it into the schedule where possible and use the unit's activities as an extension of your existing curriculum. Since these unit investigations were developed to foster a STEM approach to learning, they do not have to be tied to any specific time frame or topic in the science curriculum.

To get the most out of a unit, it is suggested that a few sessions be allotted to complete the activities. These can be spread out as needed. Usually, an activity can be done in about an hour. For those fortunate enough to have a one-and-a-half-hour lesson, students will have more time to explore the variations in each project and extend their creative explorations. The activities are hands-on, practical and engaging and may be well-suited to a Friday afternoon session, when students would find a sit-down lesson more draining. Remember that the unit activities can also be broken into more than one session! Be sure to allow serious time for both journalling and recording information within each period.

Vocabulary and Discussions

Share and discuss unit vocabulary lists with students. Identify and use the terms frequently throughout the sessions to reinforce essential subject-area vocabulary. Enlarge each list to create posters for student reference, or photocopy the list for each student to keep in their journalling notebooks.

Encourage discussions within groups and between groups if they are focused on the topic. Also allow some time for the teacher-moderated colloquium in which individuals share their experiments, results and conclusions based on their research.

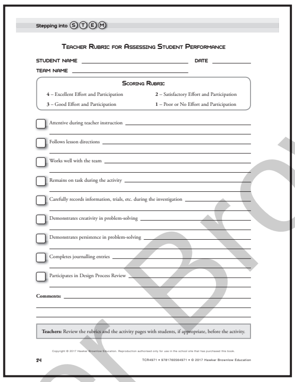
A general activity period could allow 5 to 7 minutes for teacher introduction and review of previous learning, 5 minutes to efficiently distribute supplies and 30 to 40 minutes to complete the activity involving science, technology, engineering and maths. The remaining time should be devoted to science journalling.

Teacher and Student Rubrics

Use the teacher rubric on page 14 to evaluate team progress, time on task, student interaction and to reinforce STEM objectives. Students who are focused on the objective and methodically trying different ways to solve a problem are doing science. So are those who are responding a bit randomly to their own ideas and trying them out.

As student groups work through each investigation, they should complete the student rubric on page 15 to reinforce the processes they used and to reflect on the procedures they followed.

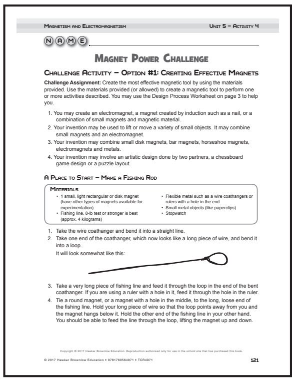
NOTE: Explain both rubrics to students before starting the units. It is important for them to know how their work will be evaluated and what steps they should follow as they work on a unit investigation.

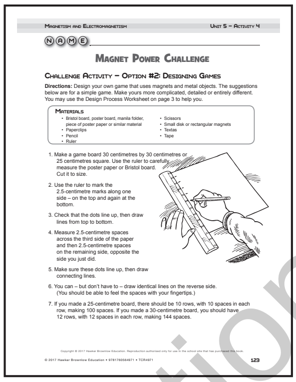

Teacher Rubric for Assessing Student Performance

Challenge Activity

Each of the seven major units has a challenge activity as the last activity. Students are given lists of suggested materials and advised to look over their journals about previous activities in the unit for hints and ideas. For example, students doing the bridge activity are challenged to build a suspension bridge. Students will have noticed in previous experiments which aspects of the different bridges held the biggest loads and which materials held up the best.

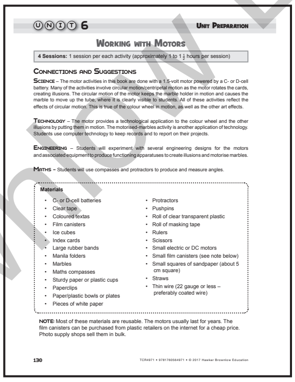
There are also some directions and suggestions in each Challenge lesson to guide students who need them. Allow time for frustration, imagination and so forth to set in during the building period for each of these challenge assignments. Use the marking rubric for creativity, success, effort and on-task work time.

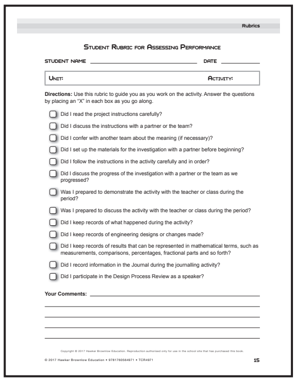

Magnet Power Challenge


Magnet Power Challenge

Team Management and Materials

In this explosive era of scientific knowledge and discovery, teamwork matters; all children need the kinesthetic experiences and collaborative interaction with their peers that are essential aspects of science instruction.


Working with Motors


Student Rubric for Assessing Performance

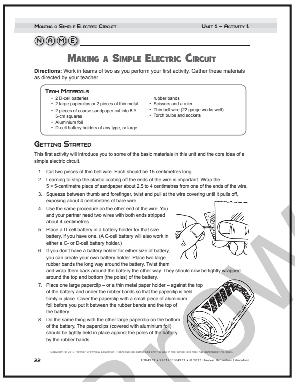
The activities in this series were designed to maximise student participation. Students will work in pairs or small collaborative teams. The collaborative process is essential to construct the apparatus and create the models. *Four hands and two minds working together are more efficient and effective than individuals proceeding alone.*

Materials used for the STEM activities in this book are not from expensive science kits. Those kits tend to not provide enough materials to engage all students simultaneously. Virtually all of the materials used in this series are available at relatively inexpensive cost at local chain stores and discount shops. Other materials are available in local hardware or craft shops.

Lesson Notes for the Teacher

Lesson 1 – Guided Activity

The first lesson is designed so that the teacher can guide and control the pace of the activity and can ensure that students know how to function in this type of science activity and with these materials. It is more teacher-directed in terms of time and following specific directions than later lessons in the unit. As an example, look to Unit 1 – Electric Circuits, Activity 1. Teachers will be able to use this activity to introduce their students to the concepts explored throughout the unit. They are able to direct students through the building of a simple electric circuit, providing students with the basal knowledge they need to guide their own learning in later activities.

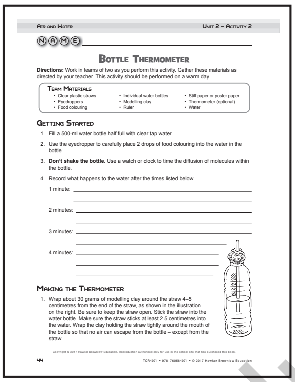


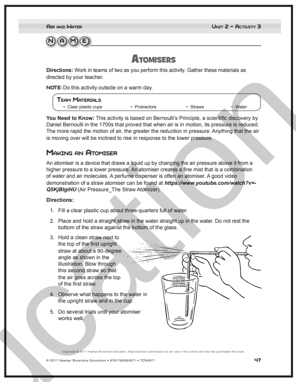
Providing guidance through the beginning phases of each unit will set the stage for student groups to continue with their investigations and discussions throughout the units. This is also an opportunity for the teacher to note which teams or students might be struggling, and to provide more assistance to them.

Lessons – Your Turn

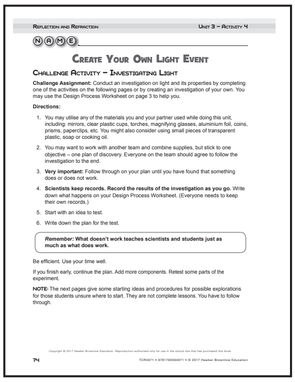
Review students' findings and ideas related to their investigations in Activity 1. Discuss how students will be exploring how a project works under various conditions. This can be an independent collaborative group activity. Students can work in pairs. In Unit 2 – Air and Water, students work in teams and apply the knowledge they have gained in Activity 1 about condensation and evaporation to build a bottle thermometer. In later activities, students learn about Bernoulli's Principle and atomisers and design an invention applying all of these concepts.

The second and third lessons (and sometimes a fourth) allow students to work at their own pace as they do the lesson. The teacher circulates through the room giving advice, encouragement and correction as needed. Students work in pairs.





Final Lesson – The Challenge



The final lesson in each unit involves a Challenge Activity in which students apply what they have learned in earlier lessons in order to solve a specific problem or to make the fastest, best or most unique application of the concepts learned. Students work in pairs and use the Challenge Activity for Unit 3 – Reflection and Refraction to either conduct an investigation on the properties of light or design their own investigation. In this challenge, students are encouraged to use the Design Process, just like adult engineers.

About Teams

Although there are always students who prefer to work alone – and have difficulty working with others – most students quickly find that these projects need three or four hands working in unison to work well. Most students also realise that the opportunity to share ideas and experiences helps their own performance and is reflected in their success in a project.

You may want to have students switch partners when you start a new unit or after partners have been together for a few units.

Electric Circuits

4 Sessions: 1 session per each activity (approximately 1 to 1 $\frac{1}{2}$ hours per session)

Connections and Suggestions

Science – Students will explore different sources of electricity and the flow of electrons in a closed path of a complete circuit. They will build their own complete circuit using batteries as a voltage source, as well as explore real-world applications of circuits when they build a telegraph. They will also learn about the importance of conductors and non-conductors.

Technology – Students can use the internet to research electricity and its different sources, as well as the circuits that are in many everyday devices. They may also research the discovery of electricity and its impact on technology throughout history, as well as the resulting communication technology. They may research images and diagrams of closed circuits and telegraphs in order to help them create the projects in each activity. Additionally, students can photograph or record their observations and responses as they create closed circuits and build telegraphs. They might also describe the problems encountered, the solutions attempted, the success rate of each activity, different approaches used and suggestions for improvement. This can be done in an online journal, blog or even in a simple Word document.

Engineering – Students will use the design process to create a variety of electrical circuit designs. They will be able to test the most effective combination of supplies and troubleshoot when a circuit is incomplete and/or the light bulb doesn't light. A discussion can ensue regarding how electrical engineers design the circuits and batteries in the devices and appliances we use every day.

Maths – This unit requires students to measure lengths of wire as part of the set-up instructions for most of the electrical experiments. They will also record their observations using charts and diagrams. Students can also determine the ratio of bulbs lit to batteries used.

Materials

- 1 box of 100 large paperclips
- 5 sheets of coarse sandpaper (for stripping the rubber-coated ends of the bell wire)
- D-cell batteries
- Electric torch bulbs
- Electric torch bulb sockets
- 30 metres of thin insulated electrical "bell wire" (22 gauge works well)
- AA and AAA batteries
- C-cell batteries
- D-cell battery holders or large rubber bands
- Aluminium foil
- Rulers
- Scissors

Optional:

- large steel or iron nails
- wire stripper or pliers

NOTE: Most or all of this material is reusable several times.

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