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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. It is imperative that students learn these collaborative skills, but acquiring these skills is not without challenge. *Stepping into STEM: Year 3* 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 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 make during an activity will not work. This can turn into a very positive experience since knowing what won't work (and why) can possibly 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 immediately assess what students comprehend and to adapt curriculum accordingly.

Connecting Science, Technology, Engineering and Maths

STEM activities blend science and engineering learning experiences. Technology – both simple and high-tech – provides the framework for recording information. Phones, tablets and computers are effective in recording and comparing activity results. The maths element might involve sequencing, patterns, or recognising shapes, size and volume. Comparisons are 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 and engineers share ideas, experiments and solutions – as well as failures – with colleagues around the globe. Student scientists and engineers, like their professional counterparts, need experience working with partners while 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 objective.

Successful teams are able to work together and to be respectful even when they disagree. Each team member must also be responsible and accountable for their part of the work. Depending upon the activity, students may use the Design Process or the Scientific Method in order to accomplish their objectives.

A basic requirement of these collaborative efforts 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, then methodically test each one for its useful application in the activity.

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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. This is part of both the design process used by engineers and the scientific method employed by scientists.

Students need to apply their learned experiences in these activities, and 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. In order to accomplish this task, 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 and experimentation. They examine the ideas generated in the free flow of comments and discussions. They determine which ideas can be tested and then carefully compared for useful application to the problem. They keep open minds. 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.

"Show me."

"Let's check it out."

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

One of the hallmarks of a scientist is the inclination to ask questions. Another is making 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 that use academic vocabulary and by developing creative ways to test possible solutions.

The 4 *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. The natural phenomenon can be as simple as a student's swing moving back and forth, 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 length of the siphon hose in the ditch?"

In the simplest form, to **Inquire** is to 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 interpreting 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 behaviours in varying circumstances. Measuring these things in mathematical terms provides the opportunity for valid comparisons as well.

3. Interaction requires student scientists to collaborate with one or more classmates. Together they assess the problem or question, determine and carry out an investigation, and analyse the results.

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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 can end up engaging in distracting behaviours. Teams of two require the active involvement of both individuals in all phases of the activity, all the time. The one 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 each team's basic activity. 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 *I*s in a science activity, *i.e.* the effort to create or invent a solution, modification or improvement. This can be the most challenging aspect of the activity. At first, suggestions tend to be far out, impractical, silly or impossible to realise 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-facts sheet, 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 students should keep journals recording the investigations on which they have been working. With continued practice, students will develop the habit of journalling after each period of investigation. It is easier for students to keep information in one place and to refer back to previous investigations for discussion and record-keeping purposes. Consider having students use three-ring folders to keep unit pages together with additional notes, ideas and sketches.

It is suggested that a separate entry be made for each investigation session. Have students enter the date and investigation title for each new entry. Include a key question for each activity. This is the starting point for each investigation. As students proceed, 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 fishing line was doubled or cut in half, this is critical information. If the weight was doubled from 8 grams to 16 grams, it should be noted, and then the effect of the changes should be recorded for each subsequent trial.

The most important information in the journal should be the research team's conclusions about 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.

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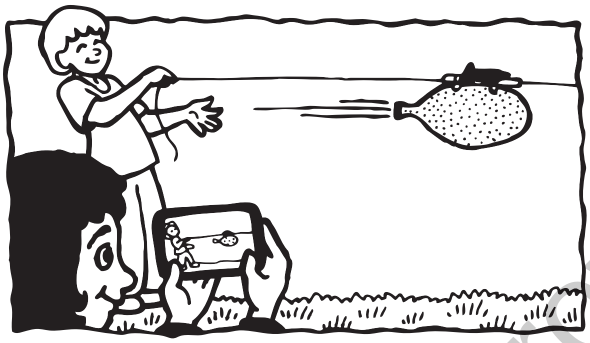
The Review Discussions

The journal entries should also be the "notes" student scientists use when sharing their information during each class review discussion. Either the *Design Process* or the *Scientific Method* can be used, depending on the topic. The teacher can act as the moderator of each discussion and should ensure that each student gets an opportunity to share their experiences, results and scientific observations. These discussions work well as 10-minute closure activities at the end of each activity 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 the 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 20 minutes to complete these activities.

You may choose to act as moderator. You can allow students to share, as teams or as individuals, about each activity and other activities 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* in which you draw conclusions and highlight the core learning concepts embedded in the activity.

Unsuccessful periods happen in any kind of class, no matter how capable the instructor or how gifted the class. Myriad things can go wrong – announcements can break the flow of instruction, an activity goes awry or one of the countless other distractions of school life can occur. You may get a true scientific discussion going but 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 period can make their day – and yours, too.

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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 to 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 you are more familiar with or those which fit your school schedule better. The organisation of each unit moves from teacher-directed activities, to more student-driven activities, to a final challenge activity which allows students to create their own unique products or inventions. In total, *Stepping into Stem: Year 3* contains six units. Students should be encouraged to follow the Design Process while doing the activities in each unit. The six 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 and have them close to hand for quick-reference during each activity.

The units include the following concepts:

- Boats and Barges: buoyancy, flotation, measurement
- Working with Sound: amplification, soundwaves, vibrations
- Solutions, Mixtures and Emulsions: chemistry, emulsions, reactions
- Air in Action: air in motion, aeronautics, designing machines
- Simple Machines: wheels and axles, wedges, inclined planes, levers, pulleys, screws
- Classroom Chemistry: chemicals, capillary action, measurement

Pacing Units and Lessons

The amount of time allotted for completion of each unit can vary. You may choose to utilise some or all of the units and can intersperse 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 subject in the science curriculum.

To get the most out of a unit, it is suggested that a few sessions be allotted in order 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 period, students will have more time to explore the variations in each project and to 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 focused time for journalling and recording information in each period.

Vocabulary and Discussions

Share and discuss the STEM Vocabulary List (page 15) and the unit vocabulary lists with students. Identify and use the terms frequently throughout the sessions in order to reinforce essential subject-area vocabulary. Enlarge each unit list in order to create posters for student reference or photocopy a list for each student to keep in their journalling notebook.

Encourage discussions within groups and between groups as long as the discussions are focused on the topic. At the end of each activity, allow time for teacher- or student-moderated review activities, in which individuals share their experiments, designs, results and conclusions based on their research.

A general activity period could allow five to seven minutes for teacher introduction and review of previous learning, five 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.

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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.

For example, in Unit 1 – Boats and Barges, teachers will guide the teams through the process of constructing and testing the function of boats made from clay. This will reinforce basal knowledge and provide a foundation for the extension 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 or students can work in pairs.

For example, in Unit 2 – Working with Sound, after learning about the properties of sound, students apply this knowledge by building plastic cup telephones and guitars in later activities.

The next two or three lessons allow students to work at their own pace as they do the activities. 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 should work in pairs.

This section challenges students to apply STEM concepts to an invention process. For example, in the challenge activity for Unit 3 – Solutions, Mixtures and Emulsions, students will extend their learning by using the Scientific Method to design and test their own chemistry experiments.

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Boats and Barges

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

Focus: Physical Science – buoyancy, flotation

Connections and Suggestions

Science – Students will be exploring Archimedes' Principle and constructing boats capable of carrying cargo (coins). Clay, aluminium foil, styrofoam and plastic frozen food or takeaway containers are used in the four activities in this unit. These durable materials work well with the surface tension of water to support the flotation devices in these activities.

Modelling clay is denser than water and would ordinarily sink. In the activities in this unit, students will reshape a clay ball into forms that will float. Clay is lighter than water when spread out over a wide enough area. It is generally waterproof and reusable as well. As a result, modelling clay is especially useful for buoyancy and flotation experiments. (Try to purchase clay in 500-gram boxes.)

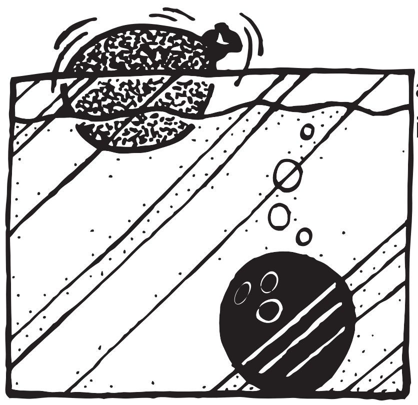
Note: Playdough does not work because it disintegrates in water.

Technology Applications – Students can use computers or personal tablets to do research on displacement, buoyancy and Archimedes' Principle. Additionally, they can photograph or record their observations and responses as they create boats, rafts and other floating vessels. They might also use computer software to record the problems encountered, the solutions attempted, the success rate of each activity, different approaches used and suggestions for improvement.

Engineering – Students will work using the design process to build vessels and to determine which designs will support the most weight without sinking. Students will be able to explain why some boat designs work better than others.

Maths – The measurement applications in this unit require students to record the precise number of coins used and to compute the coins' weights. (**Note:** Australian 5-cent pieces issued after 1999 weigh roughly 2.83 grams.)

Discussion Prompt: What is Archimedes' Principle?



Archimedes was a Greek scientist who lived long ago. He made his discovery while having a bath! He discovered that an object placed in water would float if the displaced water weighed more than the object doing the displacing. For instance, if a 12-pound (approx. 5.44 kilograms) bowling ball is placed in water, it will sink because it only displaces 10 pounds (approx. 4.53 kilograms or litres) of water. A balloon that is the same size as the bowling ball will float because it weighs less and displaces (or moves) less water.

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Working with Sound

5 sessions: 1 session for each activity (approximately 1 to 1 ½ hours per session)

Focus: Physical Science/Physics – working with sound

Connections and Suggestions

Science – This unit explores the structure of the ear and how auditory nerves are stimulated by vibrations that come from moving objects or the air. Students will be learning how these vibrations, or soundwaves, create the sounds we hear.

Different ways to create vibrations will be explored using fishing line, cups, paper tubes, rubber bands and other materials. Students will make aids for hearing, telephones, megaphones and a variety of instruments to expand their understanding of sound and vibrations.

Technology Applications – Students can use computers or personal tablets to do research on sound, hearing and devices that produce or transmit sound.

Students may digitally record research notes, ideas and responses as they create a variety of listening devices and musical instruments. They might also take photographs or film their explorations in order to compare the results of their various engineering designs.

Engineering – Students work through the design process to make products that create sounds, magnify sounds and/or transmit them. They will create and use musical instruments and telephones to explore vibrations caused by different types of objects. Students will need to measure the effects of different actions and materials and make judgements about the utility of each material used.

Maths – Students will be measuring different solid materials in order to create products. They will use addition and subtraction to aid in the creation of listening devices and musical instruments.

Discussion Prompt: How do we hear sounds? For instance, how does the sound of a siren get from the fire-engine to your ears?

Sounds, or soundwaves, are invisible waves. We can't see them but we hear the vibrations created when an object moves, or vibrates. When the vibrating object causes the air (or material) around it to move, it creates waves known as soundwaves. These waves, or vibrations, travel to our ears and then to our brains. Our brains translate the vibrations into the sounds we know. Our ears have three main parts that work together to help us hear. (See page 45.)

Extension: Have students take turns flapping rulers or dropping unbreakable objects on their desks in order to feel and hear the vibrations. Ask them to lay their heads on their desks to see if it makes a difference in the sounds. Compare the sounds of heavier and lighter items.

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