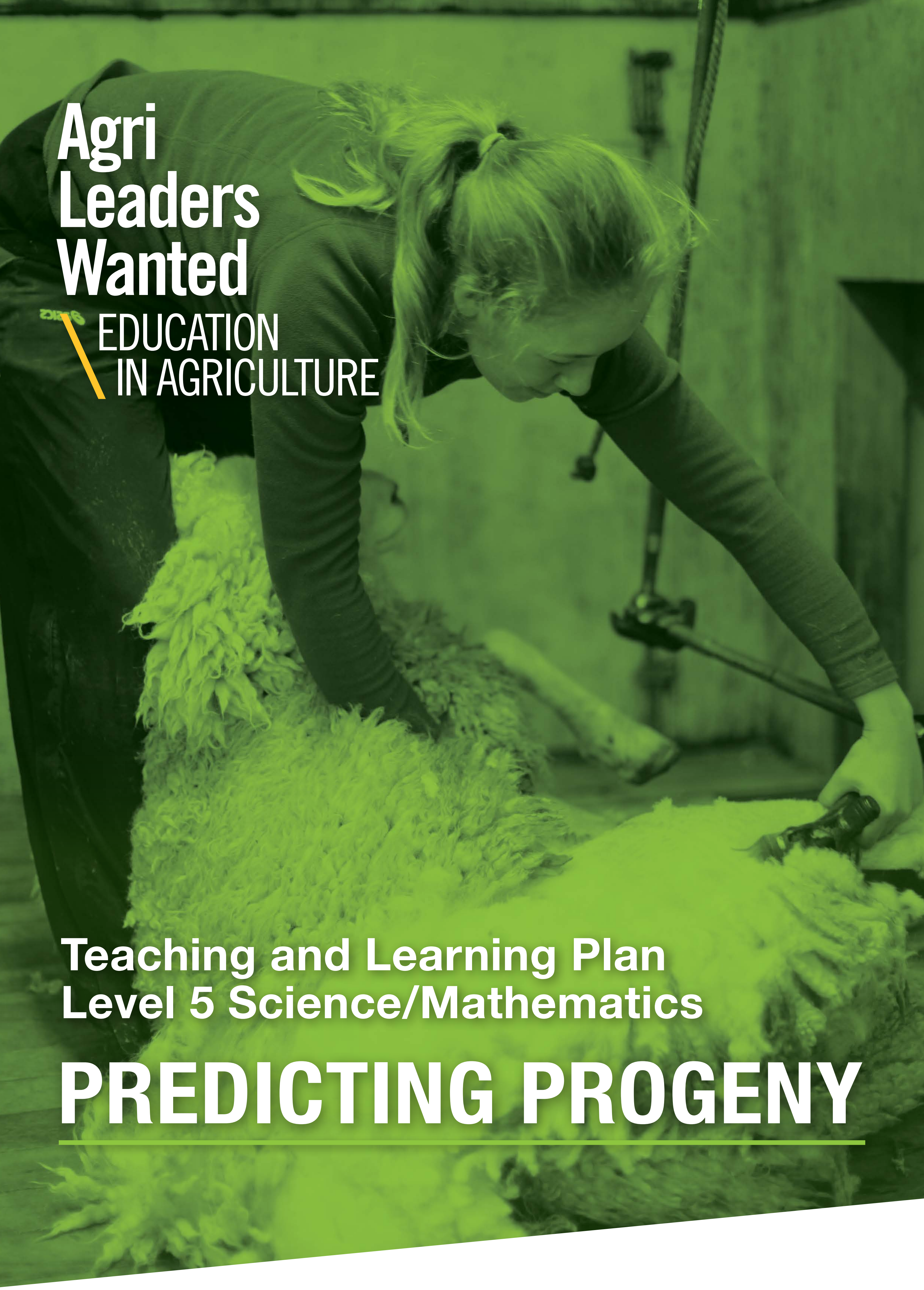

Agri Leaders Wanted
EDUCATION IN AGRICULTURE

Teaching and Learning Plan
Level 5 Science/Mathematics

PREDICTING PROGENY

Contents

This resource has been funded by the Red Meat Profit Partnership, in conjunction with NZ Young Farmers and CORE Education.

Context

Sheep and cattle are the most widely farmed animals in New Zealand:

- 44% of all farms in New Zealand farm sheep and beef
- there are a total of 29.5 million sheep and 3.6 million beef cattle in New Zealand (Farm Facts 2016).

In New Zealand, as in most agricultural societies, sheep and cattle breeds have been modified using selective breeding techniques and our knowledge of genetics to produce more meat, more milk, and better wool; and for stock to live longer, resist diseases better, and cope with different environments. Being able to strategically plan for particular traits and predict outcomes in offspring has been very useful for farmers.

This is a cross-curricular unit of work in which junior secondary students develop skills specifically related to Level 5 science (S) and Level 5 mathematics and statistics (M&S).

Students learn about:

- recessive and dominant traits in sheep and cattle breeding (S)
- the likelihood of certain genetic traits being passed on to offspring (S)
- solving genetic problems through the use of Punnett squares and pedigree charts (S)
- comparing and contrasting experimental probability (using a random number generator) with theoretical probability (using tree diagrams) (M&S)
- applying the probabilities derived from their work on Punnett squares and pedigree charts to probability problems based on breeding animals in a farming context (M&S)
- using a random number generator to create simulations to model experimental probability
- writing reports of their findings.

Curriculum links

Key competencies

The New Zealand Curriculum identifies five key competencies. As students work on the activities in this resource, they use and develop the key competencies.

- Participating and contributing: Contributing to class discussion and participating in group tasks, particularly those that involve research or debating the positive and negative impacts of technological developments
- Thinking, both creative and critical: Exploring technological innovations such as robotics and automation, the new possibilities they have opened up, where they might go in the future, and their implications for individuals and the community; considering how technology both changes and responds to society; considering the different areas of specialist skills and knowledge required for technological developments
- Using language, symbols, and texts: Learning new specialist vocabulary (for example, "brix", "dry matter", "NIR") and being introduced to new concepts (for example, "supply chain", "value-added"); making sense of materials that have been written for adults working in the kiwifruit industry
- Relating to others: Working collaboratively as part of a group to develop concepts and ideas about future value-added products, the impact of robotics and automation
- Managing self: Showing initiative, following up on commitments made to the group, contributing to research.

Level 5 science

Nature of science

- Understanding about science: Students will understand that scientists' investigations are informed by current scientific theories and aim to collect evidence that will be interpreted through processes of logical argument.
- Investigating in science: Students will develop and carry out more complex investigations, including using models; show an increasing awareness of the complexity of working scientifically, including recognition of multiple variables; begin to evaluate the suitability of the investigative methods chosen.
- Communicating in science: Students will use a wider range of science vocabulary, symbols and conventions; apply their understanding of science to evaluate both popular and scientific texts (including visual and numerical literacy).
- Participating and contributing: Students will develop an understanding of socio-scientific issues by gathering relevant scientific information in order to draw evidence-based conclusions and to take action where appropriate.

Living world

Evolution: Students will describe the basic processes by which genetic information is passed from one generation to the next.

Level 5 mathematics and statistics

Statistics

- Statistical literacy: Students will evaluate statistical investigations or probability activities undertaken by others, including data collection methods, choice of measures, and validity of findings.
- Probability: Students will compare and describe the variation between theoretical and experimental distributions in situations that involve elements of chance; calculate probabilities, using fractions, percentages, and ratios.

Key understandings

- Humans have managed the form and function of domesticated animals to suit specific purposes for thousands of years, using selective breeding techniques and, more recently, the science of genetics to guide the outcomes of this selective breeding.
- The sheep and cattle industry, and other primary industries, are very important to the New Zealand economy.
- Large-scale agricultural advances have been made possible by scientific and technological developments.
- Many of these developments have been pioneered in New Zealand.
- Scientific and technological developments draw on multiple areas of specialist knowledge and skills.
- Continuing development is necessary for reasons of competitiveness, but not everyone benefits.
- Customer (client) expectations and preferences are a major influence on technological developments in agriculture.
- Technology is making it possible for sheep and cattle farmers to improve their production outcomes.

Background information for teachers

New Zealand is dependent on a number of different breeds of sheep and cattle, some of which have been bred in New Zealand to suit our environment.

The Hereford is a hardy breed of cattle and can be farmed in a wide range of environmental conditions. The cows are highly fertile and calve easily. Herefords convert feed to meat efficiently and produce a high quality carcass. The traditional Hereford is horned but a polled type was bred in the US and imported into New Zealand in 1929. Horned cattle can cause many problems while on the farm, in transit, and at the meatworks. The gene to produce polled offspring is one worth breeding for. Hereford cattle are adapted to the high (and hill) country, and as a result, became a popular choice for farmers in New Zealand.

The Corriedale is an example of one of the first sheep to be bred to suit New Zealand's environment. As early as 1868 a farmer crossed merino sheep with longer-wool varieties to produce what then became known as the Corriedale, named after the station in Central Otago from where it was originally bred. It provides high quality wool and meat and vies with the merino as one of the more popular breeds for farmers. Other examples of New Zealand-bred sheep breeds are Drysdale, NZ Romney, Perendale, and Coopworth. These have all been bred to enhance other desired characteristics, such as higher fertility rates and hardiness in a range of different environments.

All these breeds of sheep and cattle have been developed using:

- our knowledge of selective breeding to achieve a specific goal
- the ability to predict the outcomes in offspring.

Resources:

- Sheep breeds in New Zealand
- Beef cattle breeds in New Zealand

Prior knowledge required

- MRS GREN life processes – specifically reproduction
- Probabilities range from 0 (impossible) to 1 (certain)
- How to draw and read tree diagrams
- Basic numeracy skills – fractions, decimals, percentages, ratios.

Key concepts covered

1. Chromosomes, genes, DNA:
   - the structure and function of DNA in general: nucleotides, base pairs, double helix
   - the relationship between DNA, genes, alleles, chromosomes: DNA is a molecule; genes are specific base sequences that code for a trait; alleles are all alternative forms that a gene can take; chromosomes are the macrostructures that hold a series of genes.
2. Traits:
   - traits are characteristics that are passed on from one generation to another
   - they can be discrete or continuous and dominant or recessive
   - traits selected for in cattle are reproductive success, weight gain, growth rate, longevity, polled, coat colour
   - traits selected for in sheep include reproductive success, weight gain, growth rate, longevity, wool qualities and fleece colour
   - some of these traits may have a direct impact on meat or wool production, others have indirect impacts (for example, polled). Others have no impact (for example, coat/fleece colour).
3. Cattle have 60 chromosomes in each somatic cell: 29 pairs of autosomes and 1 pair of sex chromosomes (XX for cows, XY for bulls).
4. Sheep have 54 chromosomes in each somatic cell: 26 pairs of autosomes and 1 pair of sex chromosomes (XX for ewes, XY for rams).
5. Where do lambs and calves get their chromosomes from?
   - process of gamete production via meiosis
   - sexual reproduction
   - formation of homologous pairs
   - karyotypes.
6. Heterozygous genes are a pair of genes where one is the dominant gene and one is the recessive gene. Homozygous genes are a pair of genes that are the same –two dominant genes or two recessive genes.
7. Genotype refers to what the genes are – homozygous recessive. Phenotype refers to what the individual looks like, for example, polled, horned, black fleeced.
8. Monohybrid crosses only look at one trait at a time.
9. Constructing Punnett squares to show the genotypes from a monohybrid cross and using this to predict the probability of phenotypes appearing from a particular cross.
10. Variations:
    - Discrete variations: For example, male versus female; polled versus horned
    - Continuous variations: For example, weight, milk production (for feeding offspring), muscle (meat) development.
11. Impact of the environment on phenotype expression: Some traits are affected by the environment; milk production for feeding offspring or weight gain are affected by the quantity and quality of food.
12. Long run relative probability; simulations, calculation and comparison of theoretical and experimental probabilities.

These concepts can be taught using resources from the following sites:

- CensusAtSchool, Resources for teaching statistics, NZC level 5
- Beef and Lamb New Zealand, *Compendium of New Zealand Farm Facts*

Activity 1: Build a bovine

When farmers plan to breed sheep or cattle for particular desirable characteristics or traits, they use knowledge gathered over thousands of years of selective breeding. These days we have a lot more information about the science behind this selective breeding, based on our knowledge of genetics, inheritance, and probability theories. This means farmers can expect to get a higher level of these characteristics or traits appearing in offspring.

In this activity, students “design” and draw a calf, using the facts given below about some dominant and recessive traits in cattle. They take the part of one of the parents and then use a random generator tool (a coin) to select which gamete they contribute to their offspring once they find a mate to “breed” with.

Students are to draw a picture of their calf, using the clues and the outcomes of their random allocation of allele from the list provided. They will need a coin (the random generator) to toss, so that they can choose the alleles that either the cow or the bull contributes towards making the calf.

(HINT: You could provide a standard outline of a calf for students to use to draw in their outcomes.)

Traits and alleles

The drawing of the calf will be made up from the following traits and alleles:

- Sex: XX indicates a female, XY a male
- Coat colour 1: black (B) is dominant to roan (b)
- Coat colour 2: solid colour (C) is dominant to having white patches (c)
- Coat texture: smooth coat (S) is dominant to rough coat (s)
- Horns: polled (P) is dominant to horns (p)
- Feet: cloven hooves (H) are dominant to smooth hooves (h)
- Face: white on the face (W) is dominant to solid face colour (w)

Students start by tossing a coin to determine whether they will be the mother (heads) or the father (tails) for this investigation. This determines the column they fill in first on the table provided (the mother’s gametes or the father’s gametes).

Students then decide whether the heads will be allocated to the dominant allele or the recessive one when they toss their coin.

They toss a coin for each trait for the parent they are acting as, to decide which allele will be in the gamete formed and contribute towards producing a calf. (If they are a female, the sex allele can only be X so that is already filled in.)

	Mother's gamete allele	+	Father's gamete allele	=	Calf's genotype	Calf's phenotype
Sex	X					
Coat colour 1						
Coat colour 2						
Coat texture						
Horns						
Feet						
Face						

Once students have worked out the alleles for the parent they are, they find a partner of the opposite sex to 'breed' with. They record their partner's alleles on their table, and then work out the genotype and phenotype of their offspring to complete a picture of what their calf will look like.

Activity 2: Counting sheep

For centuries sheep have been selectively bred to produce white wool, the main stimulus being the development of dyes, which allowed a wider range of colours to be produced than the natural black, grey and brown wool of most of the natural breeds of sheep. This selection for white sheep is likely only to have masked the presence of colour genes in modern white breeds, due to the inhibiting action of the white gene. It is not uncommon for black or coloured lambs to appear in a white flock, but these lambs are usually culled immediately. However, what is not always recognised is the fact that to produce a coloured lamb, both parents must be carrying a gene for colour.

(Black & coloured sheep breeders ASSN. of Australia (Vic.) Inc., Basic concepts of colour inheritance)

- Students use the introduction above and their own research to predict which colour of fleece in sheep is the dominant allele and which is the recessive allele.
- Using any letter of their choice to indicate the allele responsible for fleece colour, students construct a series of Punnett squares to show all possible genotypes and phenotype ratios when two white sheep are breed together, and when a white sheep is bred with a black sheep.

Meri has a small flock of 100 sheep, most of which are white fleeced and some are black fleeced. She sells her fleeces at the local farmer's market and has been asked to supply a local wool spinners group with more black fleeces than she currently has.

- Students work in groups to write Meri a breeding action plan for how she can increase the black-fleeced proportion of her flock to be able to meet this demand for black fleeces. The plan needs to use the correct terminology and provide a scientific explanation of how this plan may work, using knowledge of genetics, probabilities, ratios and Punnett squares.
- Students create an infographic to show the main breeds of sheep in New Zealand and the traits they have been developed to enhance.

Activity 3: A cattle conundrum

Polled cattle are cows that are born with no horns. This is a desirable genetic trait because cattle with horns can be dangerous to other cattle and to the people who work with them. When pure for this trait cattle do not carry the gene for horns. In cattle, the allele for polled is dominant, while the allele for horns is recessive.

Rawiri wants to increase the number of polled cattle in his herd so he is thinking of buying a polled Hereford bull. He was told that it is a polled purebred bull, which means that it will only sire calves with no horns. The bull shows no physical signs that it has ever had horns, but he is not sure what its genotype is as he knows that the phenotype does not always indicate the genotype. He needs to find out if the bull is a polled purebred animal as he does not want to buy this bull unless he can be guaranteed that it is pure for the polled allele.

A plan for action - Possibilities and probabilities

- Before starting, students need to research and review the key terms: “homozygous”, “heterozygous”, “dominant allele”, “recessive allele”, “purebred”, “genotype”, “phenotype”, “monohybrid cross”, and “testcross”.
- Students investigate all the possible genotypes that the bull could be if its phenotype is polled.
- Using all the possible genotypes that the bull could be and all possible genotypes heifers (polled and horned) could be, students use a range of Punnett squares to show the different phenotypic ratios and probabilities of offspring resulting from a number of crosses between this bull and heifers. They should indicate which genotype of heifer would be the best one to breed this bull with and justify their decision.
- Students use their results of their theoretical probabilities to produce a report for Rawiri, advising him of a plan that would best determine whether his potential bull is pure for the polled allele or not.

Running a mathematical simulation

When carrying out a testcross (homozygous recessive) to ensure his sire is polled purebred (PP), Rawiri wants to have as few calves born as possible. Using the results from their report, students determine the probability of getting a polled calf sired by a bull which is Pp.

- The probability of a calf having horns - P(H) =
- The probability of getting a polled calf - P(P) =

To simulate the result of a single birth (horned or polled), an appropriate random number generator (calculator, die, coin, spreadsheet, or spinner) can be used.

For example, if the probability of getting horned calves was 3 out of 8, then an eight-sided die could be used. If a 1, 2, or 3 is rolled, the calf would have horns; if 4, 5, ,6 ,7 or 8 is rolled, it would be polled.

Students run 50 trials of a simulation to get an idea of how often a “typical” calf will be born versus how often a calf with horns will be born.

A single trial of the simulation will consist of using the random generator until a calf with horns is born. The results for each of the dice rolls and the number of dice rolls for each trial is recorded in a table. Students put the results from this table into a dot plot graph for further analysis.

Data

An example of a table

Trial Number	Results	Number of births required for horned calf
1	H	1
2	PPH	3
3	PPPPH	5
4	H	1
….		
50	PPH	3
	Total	

An example of a dot plot graph

Number of births required for horned calf

x									
x	x								
x	x								
x	x	x							
x	x	x		x					
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Students use the following sentence starters to write up their results and conclusions

- I notice …
- I wonder …
- I recommend … because …

Assessment

This activity could be used as an assessment activity. Students would be expected to:

- demonstrate correct use of Punnett squares
- run the simulation
- write up the simulation, using PPDAC
- correctly use scientific terms such as:
  - "genotype" and "phenotype"
  - "dominant" and "recessive"
  - "homozygous" and "heterozygous"
- correctly discuss the use of a testcross to identify the genotype of the bull.

Activity 4: What you see is what you get

Rawiri has discovered that his bull was not actually polled purebred (PP) but is a heterozygous polled bull (Pp). He is now expecting calves from five of his Pp heifers.

- Students use Punnett squares to determine the probability of the calves inheriting the polled trait.
- Students use experimental probability to model this process of having at least 3 of the calves inheriting the polled trait.
- Compare the experimental probability with the theoretical probability of having at least 3 of the calves inheriting the polled trait.
- Students present a report of their findings. They can choose how to present this report. They must use the correct scientific terminology and show all necessary calculations and diagrams.

Extension activity

The students carry out a simulation to generate probability and to compare this value with the calculated theoretical probability.

Prompts from the teacher could include:

- Use your calculator to generate a random number. (Instructions could be provided depending on the probability of the given trait.)
- Run this simulation for 100 trials.
- Highlight the successful trials (exactly two of the animals with desired trait).
- Calculate the experimental probability of getting exactly two animals with the desired trait.
- To calculate the theoretical probability, set up a probability tree to show all the possible ways a pack can be filled with T (Trait) and N (not desired trait).
- Compare the two probabilities that you found.

Supporting resources

- Horned versus polled
- Bull selection
- Better beef breeding
- Feed intake and growth in beef cattle
- Inheritance basics with Punnett square crosses
- Selective breeding
- Some Examples of Dominant and Recessive Traits in Selected Domestic Animals
- Basic concepts of colour inheritance in sheep
- Basic Sheep Genetics
- Breeding Easy Care Sheep
- Wool Innovations
- Sheep Farming in New Zealand