Lesson 1: Walking at Constant Speed

Australian Curriculum: Mathematics — Year 5

ACMSP118: Pose questions and collect categorical or numerical data by observation or survey.

ACMSP119: Construct displays, including column graphs, dot plots and tables, appropriate for data type, with and without the use of digital technologies.

Australian Curriculum: Mathematics — Year 6

ACMSP147: Interpret and compare a range of data displays, including side-by-side column graphs for two categorical variables.

Australian Curriculum: Science — Years 5 & 6

ACSIS090: Construct and use a range of representations, including tables and graphs, to represent and describe observations, patterns or relationships in data using digital technologies as appropriate.

- Constructing tables, graphs and other graphic organisers to show trends in data.
- Identifying patterns in data and developing explanations that fit these patterns.

ACSIS218: Compare data with predictions and use as evidence in developing explanations.

- Sharing ideas as to whether observations match predictions, and discussing possible reasons for predictions being incorrect.

Lesson abstract

In this lesson students walk at a slow and then a faster constant speed and discover that faster speed corresponds to walking a longer distance in unit time. Students make 'streamer graphs' using paper streamers to represent the distances walked per second, using a real or virtual metronome as a timer.

Mathematical purpose (for students)

To make a graph of the distance a person walks in each second, and to interpret what it says about their speed.

Mathematical purpose (for teachers)

The focus of this lesson is to understand speed as distance travelled per unit time. Students will transition from their intuitive understanding of *faster* and *slower* and make links to distance travelled in one second. Interpreting what the strips in the graphs represent is a major focus for this lesson, that is, understanding that the strips in the graph represent both the distance travelled in one second and the speed of the walker. A faster walking speed will give longer sections of streamer. It can be challenging for students to link the physical length of the streamer to the physical quantity of speed.

Lesson Length 90 minutes approximately (possibly across two separate class periods)

Vocabulary Encountered

- Constant speed

Materials — See Teachers' Guide: Appendix B for full details

- Streamer graph materials, metronome etc.
- Workbook *ST3_Motion_Y5&6_1a_Workbook.pdf* (1 per student)

We value your feedback after these lessons via https://www.surveymonkey.com/r/JJCGHVX

Mathematics by Inquiry is an initiative of, and funded by, the Australian Government Department of Education and Training

Australian Academy of Science

aamt

Background

Speed

An understanding of speed is the basis for much of the work in later lessons. It is important for students to investigate and discuss the meaning of speed, and to see how the varying speed of an object can be represented by a column graph of the distance travelled in each second.

Speed is defined as the distance travelled per unit time. So, for example, if I travel 10 metres in 5 seconds, my speed is 2 metres per second.

Students may think of speed in less formal, less numerical ways. They probably use the words slow, fast, faster, slower, too fast etc. to describe just a physical feeling of speed. This lesson offers a way to quantify the physical experience of a slow walking speed and then of a faster walking speed.

In this lesson, students encounter the formal idea of speed as distance in one second (later, distance per unit time), but without a focus on numbers. A graph is made by marking on a streamer the distance covered in each second by a student walking at a steady pace. The streamer is cut up and arranged into a column graph.

Most students realise that strips of the same length represent the same speed — and so constant speed should result in a graph with all the strips the same length.

By using a fixed time interval (one second) for the red graph and the blue graph, we can compare different speeds. The longer the distance travelled in one second the faster something is moving — so longer strips on our graph represent faster motion. However, a surprising number of students believe that shorter strips represent faster motion. It is easy to see where this idea may come from — in many of our experiences with speed the winner (the fastest runner or car) takes the least time to complete the race. It is the intention of this lesson to establish that objects that go faster travel further in a given time.

Column graphs made from streamers

Most students believe that the graphs can be used to decide which object or person is moving faster, but very few students believe that the graphs can be used to quantify *how fast* something is moving. Near the end of this lesson, students will approximate speed from a graph.

Graphing

Good practice relating to graphing should be encouraged.

- Labelling the x-axis is tricky as there is a temptation to label it as ‘Time (seconds)’ like a line graph, rather than as ‘Time period’ or ‘Time interval’ with ‘1st second’, ‘2nd second’ etc.
- Label the y-axis as distance (rather than speed) to establish that speed is distance travelled per unit time.
- Appropriate titles are important. It is useful to keep the graphs on the wall for later reference and it is easy for the classroom to become engulfed with streamer graphs that give no indication of what they represent.

Using the metronome

Many students will have seen a metronome. Others will need to be shown how it can be used for timing and how to vary the number of beats per minute — this is also the case if using a virtual metronome. The metronome needs to be set at 60 beats per minute during the activities.

Other notes on speed

- Many different units can be used to express speed — for example, speed may be expressed in kilometres per hour, or metres per second, or the speed of the growing crack in our dining room wall might be given in millimetres per year. Students often believe that to express speed ‘properly’ it must be given in kilometres per hour. This not the case and doing the arithmetic to convert speeds to kilometres per hour is not a focus for these lessons.

- Technically the distance travelled in each second (the length of each streamer column) equals the *average* speed for that second. The speed might vary during the second. This is not explicitly discussed in these lessons. Calculation of average speed is not required.
- Speed is defined as the distance travelled per unit time. Speed could instead be expressed as time taken to travel a unit distance (e.g. a runner with a time of 15 seconds for the 100m has a speed of 0.15 seconds per metre), but having this as the convention would mean that larger numbers represent slower speeds, which may be counter-intuitive and confusing. This can be discussed as an extension activity.

Walking at a Slow Constant Speed

The challenge for this lesson is 'Can you walk at constant speed?'

Introducing the Lesson

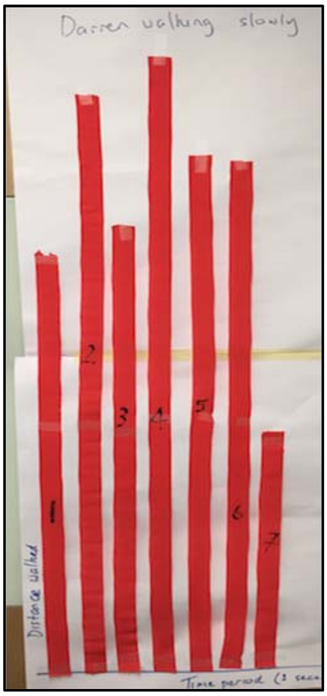
- Lay out the red streamer in a straight line along the full length of the room, leaving some space at either end [Workbook Step 1].
- Select a student (the Walker) to 'walk at a constant (steady) speed next to the red streamer — not too slowly, not too fast' [Workbook Step 2].
    - Choose a pace so as to cover the length to be walked in about 7 or 8 seconds for the first walker (in the second part of this lesson the student will need to cover the same distance in 4 to 5 seconds).
- Demonstrate the metronome.
    - Ask who has seen one before & what it is used for.
    - Explain it will be used for timing.
    - Show how to vary the number of beats per minute.
    - Ask how long each beat will be if it is set at 60. (One second per beat)
- Select a student (the Timer) to operate the metronome [Workbook Step 2].
    - The Timer is responsible for saying 'Ready! Set! Go!' in time with the metronome.
- Select 7 or 8 students (the Markers) to mark where the Walker is at 1 second intervals [Workbook Step 2].
    - Give each Marker a block and explain that Markers will put down blocks (one each) to mark where the student is at each tick of the metronome. Marker 1 places their block at one second, Marker 2 at 2 seconds etc.
    - Markers need to know their 'position' in the line — get them to practise saying their number in order.
    - Markers should not try to place blocks directly on the path of the Walker — they should be beside the line.
- Have a few practice walks.
    - Students will need to practise walking steadily — emphasise NOT stepping in time with metronome [Workbook Step 3].
- Students need to decide which point on the Walker to mark with blocks (everyone should agree to use the same position):
    - Front foot, back foot, end of a metre ruler (which can be carried vertically almost touching the ground or dragged behind like a cricket bat), etc.
- In order to involve the whole class, ask remaining students to carefully observe whether the Markers place blocks correctly — i.e. WHERE the walking student is WHEN the metronome ticks. If the class thinks that the marking was not accurate enough, the walk will need to be done again. Students can also observe the Walker to check for constant speed.

Collecting the Data

- Markers ready, the Timer turns the metronome on and says 'Ready! Set! Go!'. The Walker walks across the room, while the Markers mark positions with blocks.
- Ask the class whether they are 'happy with the result' – i.e. whether the blocks have been placed accurately enough and also whether the walker was walking at a steady pace. If the class decides that the data is not good enough, the walk will need to be done again.
    - Establish the rule that blocks are not to be removed until the whole class has decided whether the data is good enough.
- Repeat until consensus is reached that the marks are worth recording [Workbook Step 7].
- Mark a line on the red streamer at each block [Workbook Step 8].

Creating the Streamer Graph

- Number the strips 1, 2, 3, … in order from the start of the walk, making sure the numbers are near the middle of each strip and not at the mark [Workbook Step 9].
- Cut the streamer at the marks [Workbook Step 9]. (Discard the last bit of the streamer if it was not a full second.)
- Mark a horizontal 'base line' near the bottom of the butcher's paper for students to use to 'line up' their streamers [see photo *A Red graph*].
- Ask students to glue the streamers onto butcher's paper — you may need to glue two sheets of butcher's paper together to make a sheet long enough. Make sure students line up the bottom of the streamers with the base line and start with strip 1 at the left [Workbook Step 10].
- Pin or Blu Tack the streamer graph onto the pin-board or whiteboard — make sure it is displayed vertically, and as low as possible so that the next streamer graph (which will have longer streamers) can be lined up with this one at the bottom.
- Ask students to sketch the Red streamer graph in their workbooks [Workbook Step 11].
    - Students should only use the bottom half of the left hand grid so that there is space for the Blue Graph to have longer strips.
    - Try NOT to explain why they should only use the bottom half as this would influence students' predictions for the Blue Graph later. To facilitate this, you could suggest a scale such as 20cm=1 square.
    - The sketches do not need to be exactly to scale, but the overall shape is important.



A Red Graph

Class Discussion

- *What do the strips represent?* (Ans: distance travelled in 1 sec.)
- *Did the person walk at a constant speed?*
- *Which strip(s) show the slowest/fastest speed?*
    - Many students may suggest that the shortest strips represent the fastest speed. A vote may result in an almost even division of opinion in a class.
    - This point will be made more strongly after the next graph has been made (a graph of faster constant speed).
- *How should we label the axes?*
    - The horizontal axis is quite tricky — probably the best choice is 'time period' with the columns labelled '1st second', '2nd second', etc. Remember that what we are graphing is the distance for each second, not the total distance travelled up until that point.

    - The vertical axis should be ‘Distance (cm)’ — NOT ‘Speed’ as the aim is to understand speed as distance travelled per unit time.
- *What would be a good title for our graph?*
    - Choose a title that will help students recognise the graph later.
    - Make sure it includes something about SLOW walking — e.g. *Darren walking slowly*
- Ask students to finish the Red Graph in their workbooks with labels for the horizontal and vertical axes and a title [Workbook Step 12].
- *Is this what you expected the graph to look like?*
- *What do you think the graph for constant (steady) speed should look like?* [Workbook Step 13].
    - Ask students to sketch this in their workbooks.
- *Why do you think the graph looks uneven?* (These graphs are usually VERY uneven.) There are two important reasons:
    - Walker not walking at constant speed.
    - Errors in measurement:
        - Markers placing blocks inaccurately.
        - Block placement being marked on the streamer incorrectly.

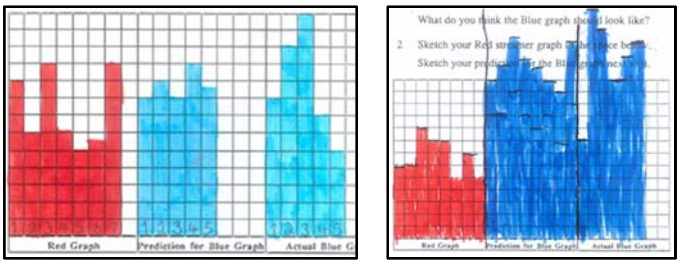
Explain to students that when we talk about ‘error’ in measurement, we don’t always mean that someone made a mistake. The ‘error’ is the difference between what we measured and what actually happened in the experiment. Some amount of error is unavoidable in experiments like this (e.g. because of human reaction times). It is important to be thinking about how to make measuring easier and more accurate. Discuss with students any ideas they might have for doing this.

Walking at a Faster Constant Speed

- This activity can be done in groups of 6-8 students (a Walker, a Timer, and at least 4 Markers).
- If you are running this lesson in two parts, here is a good place to start the second part.

Creating the Blue Streamer Graph

- Lay out the blue streamer in a straight line along the full length of the room as before, leaving some space at either end. (The streamer should be the same length as the red streamer used in the earlier part. If working in groups, each group needs a streamer and space to lay it out.)
- Ask students what they think the Blue streamer graph would look like for someone walking at a faster speed [Workbook Step 14].
- Ask students to draw their predictions for the Blue streamer graph next to their sketch of the Red Graph [Workbook Step 15].
- Select different students to be the Walker, Timer and Markers.
- Repeat the previous activity using the blue streamer with the Walker walking faster this time (about twice as fast) [Workbook Step 16].
- Use the blue streamer to make a new streamer graph.
- Ask students to sketch the actual Blue Graph in their workbooks [Workbook Step 17].



Two work samples showing the Red graph, the predicted Blue graph, and the actual Blue graph.

Class Discussion

Comparing the Red and Blue Graphs

- *How can you use graphs like these to find out which person was going faster?* [Workbook Step 18]
    - o Ask students *"What does the length of a streamer represent?"* (Ans: The distance walked in one second. This means that a longer streamer = more distance in one second = faster.)
    - o Ask students *"Why are there fewer strips in the blue graph?"* (Ans: It took fewer seconds to walk the whole length. The red and blue streamers were about the same total length, so this means that the walking was faster overall in the blue graph.)
- *Another class doing this activity produced the graph shown. In which second was the student walking fastest?* [Workbook Step 19].
    - o Some students may still think that 'shortest = fastest'.
- *How could you use the graphs to find the speed at which someone is walking?* [Workbook Step 20].
    - o Ask students how fast the person was walking in the first second. Measure the first strip (e.g. 80cm) and explain that this means the person walked 80cm in this second i.e. their speed was 80cm/s. You might like to repeat for other strips on the graph.
    - o Encourage students to find a very approximate average speed by balancing the height of the strips around an imaginary horizontal line. A numerical value can be found by measuring the height of this line in metres or centimetres, and writing the average speed in m/s or cm/s, i.e. if their line is 95cm from the bottom of the graph, the average speed is 95cm/s or 0.95m/s.
    - o The main aim here is to reinforce that speed is represented by distance per second in these graphs.
    - o If comparing the height of the strips in different graphs, highlight that this only works if the time intervals are the same in both graphs (in this case, 1 second intervals).

Student Reflection

- Ask students to write what they have learned by doing this activity [Workbook Step 21].
    - o You may wish to discuss this with the class before they write anything.
    - o Some sample responses are shown here.

No you can not walk at the same speed and lert how to graph steps

1. You can tell how fast or slow someone is walking.
2. They can be short for slow & long for fast.
3. Walking a consistant speed is walking at the same speed.

When walking at a faster speed you get longer lines because you step more in one second ~~&~~ than when you did at a slower speed. Just like how ~~are~~ car will ~~drive faster in~~ drive 100m faster than when going slow

Extension Activities

Class discussion: How fast does Usain Bolt run?

This discussion helps give concrete meaning to numbers related to speed.

Usain Bolt's 100m sprint world record of 9.58 sec was set in 2009 and is still the world record.

- Show the YouTube video of Usain Bolt beating Tyson Gay in the 2009 World Championships in Berlin https://www.youtube.com/watch?v=By1JQFxfLMM

  [There are many other versions, but this is the best one we have found.]
- *Approximately how fast was Bolt running?*
  - Is he running faster or slower than 10 metres per second?
    - How do you know?
    - How could we compare this to our walking speed?
- At around the 29 second mark in the video, it shows Bolt's speed as 37.6 km/h (it also shows that the wind speed is + 0.9 m/s, that is, there is an (allowable) tailwind of 0.9 metres per second).
  - *Can you think of other things that move at about the same speed?*
    - Cars in the 40 km/h speed zones near schools.
    - Cyclists in the *Tour de France* (not in sprints or going downhill when it is more like 60 km/h).
  - You may wish to briefly mention conversion between m/s and km/h (that is, 1m/s = 3600m/h = 3.6km/h)

Class discussion: Another way of expressing speed

- Speed is usually expressed as 'distance travelled per unit time', e.g. 40 km/h. A bigger number means a faster speed.
  - However, we also say that someone is running faster than someone else when they take *less* time to run the same distance, e.g. a runner breaks a record when they get a smaller time. In this case a smaller number means a faster speed.
  - So when we talk about the time taken to run a *fixed distance,* 'smaller = faster'.
- Are there other things that can be expressed in two ways like this?
  - One quantity that has been expressed in both ways is fuel consumption, which has changed in Australia from 'miles per gallon' to 'litres per 100 kilometres'.
  - Another example is population density, which is sometimes expressed as 'number of people per square kilometre' and other times as 'square metres per person'.
  - Population density also applies to free range egg standards:
    - CSIRO's Model Code of Practice says there should be a maximum of 1500 hens per hectare (i.e. 1500 hens per 10 000 m^2).

      This means 0.15 hens per square metre or 6.7 square metres per hen.

      Which expression do you find easiest to visualise?
    - The 2017 Australian standard allows a maximum of 10 000 hens per hectare for eggs to qualify as free range.

      Is this more or less crowded than the CSIRO's standard?

      (Ans: More crowded. This means 1 hen per square metre or 1 square metre per hen. It may be interesting to mention that, at the time of writing, this standard only applies to the hens' outdoor grazing areas, and there is no minimum time that they must be outdoors and no requirement regarding density indoors.)