TUNNELWORKS
KS3 MATHS LESSON 3 (ESSENTIALS)
TEACHERS' NOTES

About this lesson

This algebra lesson explores modelling a real world situation by creating and adding to a formula. Students work out how fast a tunnel boring machine (TBM) can bore through the ground and modify this to account for stoppage times and different types of soil that change the TBM's rate of progress.

Learning outcomes

Students can:
- Explain variables
- Use a flow diagram or other method to build a simple formula
- Use a formula to model a real world situation

Curriculum links

KS3 Maths
- Use formulae by substitution to calculate the value of a variable, including for scientific formulae.
- Begin to model simple contextual and subject-based problems algebraically.

What you will need

- KS3 Maths Lesson 3 presentation
- Lesson 3 worksheet

Students are likely to need calculators for the worksheet challenges.

Preparation

Review the KS3 Maths lesson 3 presentation. Adapt the content to suit your students' ability. Consider whether to use the 'flow' diagram method throughout to help students build their formulae step by step.

Time (60mins)	Teaching activity	Learning activity	Assessment for learning
15 mins	**Starter:** Ask students to explain how variables can help us represent numerical values from the real world. Ask students to explain how variables can be combined to model a real world situation. **Whole class:** To begin with, you may wish to show the intro video about the Thames Tideway Tunnel project if the class have not seen it before, otherwise start with screen 1. Watch the video in screen 1 and find out what students must do. Read the note at the top of the worksheet and review the key facts. Review screen 2 to find out how the Tunnel must pass through different soil types, which due to differences in rock type, stability and the ease with which the spoil (waste soil) can be removed, affect the speed of the TBM.	Students work in pairs or small groups to share examples of a variable that represents a real value. (eg s = speed) As appropriate, students suggest a way to model a situation using the variables they suggested to create a simple formula. (eg 4s = distance covered in 4 hours).	Verbal answers, discussion, questioning.
15 mins	**Individuals or pairs:** Review task 1 using screen 3 to help. If necessary, review how to use a flow diagram to build a formula. Help students identify that they can use the key facts to work out the length of a shift (8 hours) and the distance the TBM can bore in an hour. d = 8s. The TBM's speed, s = 1.188 m/hr Answer: 9.504m. **Whole class:** Share answers. Review task 2. You may want to hint that students need to introduce a bracket into their formula.	Students complete task 1, using the flow diagram method or directly writing their formula, and then substitute values into their formula to calculate the answer.	Verbal answers. Written work. Discussion, questioning.

15 mins	**Individuals or pairs:** Students complete task 2. **Answer:** d = 1.188 x (8 – b) **Whole class:** Discuss how different soils may affect the speed of the TBM. Identify that the final key facts show that it's possible to represent the effect of each soil type using a variable that acts on the formula students have created. Discuss how the maximum speed can be represented by a factor f of 1 and slower speeds by a decimal (e.g. 0.9). **Answer:** d = 1.188 x (8 – b) x f	Students complete task 2, adding a bracket and the variable b to account for stoppage time during a shift. Students suggest reasons why the TBM's speed through some soils may be faster than through others (eg hardness). Students discuss how to add the factor to their formula, taking into account that it must act on the whole formula and not just a part of it. Students complete task 3.	Written work. Discussion, questioning.
15 mins	**Individuals or pairs:** Guide students as they complete task 4 and answer the questions: 1 – Use f = 0.8 2 – Use (8 – 1) and f = 0.9 3 – Use f – 0.9. Divide the total distance by 1.5m then round down. 4 – Modify the formula to calculate 4 hours using f = 0.8 and 4 hours using f = 0.9, then add. **Plenary:** Review how each variable contributes to how students' formulae help to model the progress of the TBM through different soils. Watch the answers video on screen 4.	Students complete task 4. Share answers.	Written work. Verbal answers. Discussion, questioning.

Differentiation

Easier	Harder
As a class, begin by working out the speed of the TBM though sand and establish that one shift = 8 hours. Complete a flow diagram at each stage to model build the formula together as a class. Show students how to substitute a value for each variable. Omit selected questions from task 4.	Challenge students to build and calculate using their formulae without help. Ask students to round their answers to the nearest cm, 10cm and metre. Use the ideas in Dig Deeper.

Answers to Task 4

1. 22.81m
2. 22.45m
3. 34 rings of segments (rounded down)
4. 8.08m, rounded (3.80m in sand and 4.28m in chalk)

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DIG DEEPER

Modelling with Algebra

- Students could enter their model into a spreadsheet, creating cells into which they can enter values for each variable, and see how this changes the total distance bored under different conditions.

- Challenge students to create a formula that can account for any shift length or working period, eg

  d = 1.188 x (t – b) x f

  Where ***t*** represents the total time for the shift and as before, ***b*** represents stoppage time.

- Students could calculate the speed through different soils by multiplying the maximum speed of 1.188 m/hr by each soil factor ***f***. They could then plot distance – time graphs to represent a range of scenarios (moving though different soil types, moving from one type to another, and including different periods of downtime), and challenge other students to interpret the graph's gradients and shape to identify the soil type and what happened during each fictional shift.

- Each ring of concrete lining is made of seven segments and lines 1.5m of tunnel. Can students add to their formula to work out how many rings or segments will be needed in a specific time? (In fact, the tunnel comprises seven segments and a keystone but we have ignored this in order to keep the maths age appropriate.)

- Each ring of segments costs £600 and the TBM costs £4,500 to operate for one hour. Can students use this information to calculate the total running cost per shift? They should remember that the running costs remain even if the TBM is not moving, but segments are only required when being added to newly-bored Tunnel.