Modelling Forest Fires Masterclass

Thanks for helping with this Masterclass session! Your support is much appreciated.

The session leader should be able to tell you more about the content of the session, and exactly how they'd like you to help, but this sheet should give you some basic information you may find useful. If any of this seems obvious to you, that's great!

In general, for Masterclass sessions:

- While the session leader is talking to the group, don't interrupt them or distract the students unless something is wrong that needs fixing urgently. You should also watch and pay attention to what they're saying, to set a good example.
- If things need handing out to the students, wait for the session leader to signal you to do this, as it can distract the students if you start to hand things out before they're ready.
- If the students are given a task to work on, you should circulate the room to talk to the students. Wait until they've had a chance to tackle the problem before you interrupt them, and encourage anyone who looks like they haven't started yet.
- Try not to give away the answers to the students, especially if they're working on the problem and about to discover it for themselves - if they are really struggling, you can give them a hint or suggest where they might start looking. Asking questions about the problem is a great way to get them thinking along the right track.

In this session:

This workshop is an exploration of mathematical modelling. Models are useful tools that enable us to describe the real world and predict many things: the weather, population dynamics, the spreading of disease, the impact of an earthquakes, and many more. In this session, the students are introduced to cellular automata: mathematical models composed of grids of cells that evolve over time, according to simple rules based on the states of neighbouring cells. They will use these to model forest fires on paper.

Students will use cellular automata to model forest fires on paper grids, first using a given set of simple probabilities to simulate basic weather conditions, following which they can construct their own set of logical rules to change the model and make it their own!

The main activities are:

1. Spreading Dye worksheet activity
2. Modelling forest fires worksheet activity
3. Your Forest Fire Model Adaptations worksheet activity

There is a great deal more background information available on a separate sheet if you would like more detail. Please ask the session leader if you would like to see the additional information sheet.

Thanks again for your help with this session! If you have any other questions, please ask the session leader.

In this session:

Spreading Dye worksheet activity

Students to work on this individually. They will need access to a set of coloured pencils (shared within a group of up to four students).

Useful information:

The first example of a model introduced to the students is one where dye spreads within a square grid. In this example, the dye spreads to all squares which have three or more dyed neighbours in each time step. The session leader will have gone through an example, step by step. Probability is not introduced in this model, so all the students should have the same outcome. Because of this, *Worksheet 0* is the only worksheet with solutions.

If they 'finish' the required number of time-steps, they can either carry on or turn over and try the Game of Life activities (another practice at counting neighbours, and an introduction to an interesting cellular automata simulation).

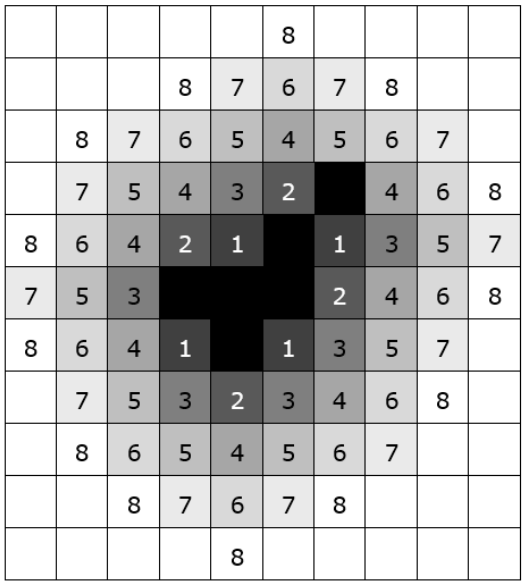
Answers to common questions/inaccuracies:

- The most important thing is to make sure that at each time step, the squares which are coloured in are the ones which are **about to be** dyed. They are then fixed as dyed for the next time step.
- Diagonal neighbours are included.
- Ensure students change colours at every time step.
- Check they have found all the required squares in the first few time-steps, as inaccuracies cause errors which continue throughout future time-steps (and it can be easy to miss some of the squares in time-step 1) – see the solutions.

Solutions:

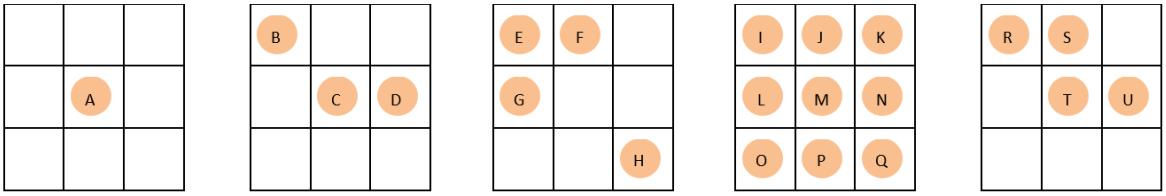
- ***Spreading Dye:*** *students should fill in each square in the following time-steps (see the diagram on the right); the number of cells dyed in each time-step are given in the table below.*

Time-step	# new cells dyed
0	*6 – already marked*
1	4
2	4
3	6
4	8
5	9
6	11
7	12
8	13



Counting neighbours: Game of Life worksheet activity

The Game of Life worksheet is another example of a cellular automata simulation, where students can count active and inactive neighbours. The initial set-up looks like this:

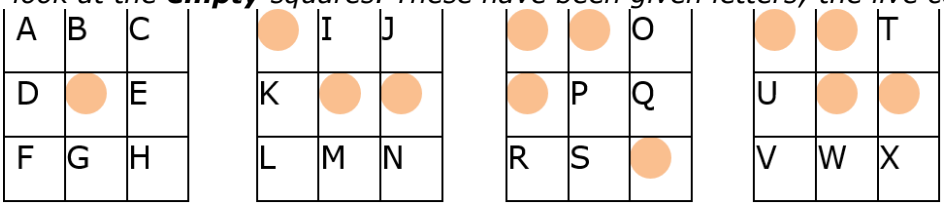


1. How many neighbours does each counter have? Fill in the table below.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
0	1	2	1	2	2	2	0	3	5	3	5	8	5	3	5	3	2	3	3	2

2. In the above arrangements, which live cells will die from loneliness? A, B, D & H
3. Which live cells will die from overcrowding? J, L, M, N & P
4. Which live cells will stay alive? C, E, F, G, I, K, O, Q, R, S, T & U

*Now look at the **empty** squares. These have been given letters; the live cells are dotted.*



5. How many neighbouring live cells does each empty cell have? Fill in the table below:

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	1	1	1	1	1	1	1	3	2	2	1	2	2	1	4	2	1	2	3	3	1	2	2

6. Where will there be a new birth? I, T & U

Modelling Forest Fires Worksheet Activity

Students will be arranged into groups of up to 4. Each group will have:

- 1 set of worksheets
- 1 set of dice (3x 6-sided, 1x 10-sided)
- 1 set of coloured pencils

Useful information:

The students will be working on a model of fire spreading across a grid. They will be checking if un-burnt trees (blank squares) catch fire by rolling the dice to see if they meet the conditions to burn. We are working in time-steps. Students will have been told to use a different colour for each time-step and ignore the colour they are using.

Trees can only catch fire from neighbouring trees which are already burning, so each blank tree touching a burning tree needs to be checked. If a tree has multiple burning neighbours, it can catch fire from any one of them – so the dice must be rolled once for each burning neighbour, and if the conditions are met, the blank tree will catch fire ready for the next time-step and can be coloured in.
Each student will have a different probability, which is noted about halfway down the sheet. Make sure they have the correct dice (those looking at the 1/10 probability should have the 10-sided dice).

Answers to common questions/common inaccuracies:

- They should use a different colour for each time-step and remember to ignore the colour they are using when counting burning neighbours – those trees are about to catch fire, but are not burning yet.
- Diagonal neighbours are included.
- If a tree escapes burning in one round, it still needs to be checked again in the next time step (and the one after that, and the one after that…).
- Stop when they get to the edge of the grid or the end of the time-steps. They might not fill the grid/table.
- If no trees catch fire in one of the time-steps, they should mark that on their sheet as 0 new burning trees and move onto the next time-step.

If they finish one grid, there are two more to repeat the experiment. They can **either** repeat the condition they were using, and see if it happens in a similar way, **or** change to another of the probabilities (perhaps swapping with another group member who has also finished). If there are fewer than 4 people in the group they can try working on the spare sheet.

If you're in a breakout room, you may wish to write the different probabilities on the board:

- Wet conditions: 1/10 chance of catching fire from one burning neighbour
- Normal conditions: 1/3 chance of catching fire from one burning neighbour
- Dry conditions: 1/2 chance of catching fire from one burning neighbour
- Drought conditions: 5/6 chance of catching fire from one burning neighbour

The session leader will ask each group to tell everyone something they noticed about their models.

- **Encourage them to discuss this in their groups beforehand** – Ask them to compare their models, look for similarities/differences in how the models spread, or pick something which surprised them about one of the models in their group (e.g. a tree lasting unburnt for ages, or the fire going in a particular direction). There are some questions on the back of their sheets (at the bottom) to help them think about what to discuss.

Your Forest Fire Model Adaptations Worksheet Activity

Students will be asked to pick one of the ideas to include in their forest fire model. They should work in their groups, or at least in pairs.

- When adding the extra factor to their model, they can either use the same conditions as before, or completely change the probabilities. If other dice are available, they may wish to use different probabilities.
- There are some ideas at bottom of page 1 of worksheet 2 to help them if they can't think what to include.
- They should pick **one** idea to focus on and try it out – if they want to do more than one, pick one to do first and try it; if it's working as expected, then add in the next thing and test that out, and so on.
- Each student should try their updated model separately and then they can compare their results (i.e. they should not share a dice).
- The questions on the worksheets are there to help them think through how to turn their idea into a rule for their models – **they do not have to answer all the questions** if they don't want to.
- The final two pages of the worksheet are the grids for them to try their models on.
- **Common problem:** Make sure the students think of a real-world factor to include and **then** think about what the probabilities will be and how to apply them using the dice on offer. Sometimes students just want to use a particular dice but can't then work out what this might actually represent (which is the wrong way round, you build a model to reflect the world, not try to make the world fit your model).

While they are working, go around to each group and check what new factors the students are adding into their model – making sure their ideas are (vaguely) realistic. For example, if they are doing wind speed, there has to be a direction; or if doing wind direction, highlight that the direction won't make a fixed area of the grid a higher probability than the rest, the direction has to be relative to the burning tree (different areas on the grid with different probabilities could be modelling a different thing). Discuss their ideas and how they see them working in the real world, and if their reasoning is logical.