THE 2022 YOUNG MATHEMATICAL STORY AUTHOR (YMSA) COMPETITION

THE CINDY NEUSCHWANDER AWARD
(THE 12-15 YEARS OLD CATEGORY)

WINNER

'Plotting For A Good Cause' by Elleanore Phillips (14 years old)
at Townley Grammar School for Girls (UK)

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PLOTTING FOR A GOOD CAUSE

By Elleanore Phillips

Townley Grammar School

Zagworld is an alluring planet renowned for a variety of weather conditions, as the random orbit path of the planet causes no weather seasons, enticing many visitors from around the universe. Some visitors come when there is a particular weather – families arrive on Zagworld from the icy outskirts of the B8-29 Solar System when the temperature for a particular day is predicted to be hot and other visitors forge towards the planet deliberately ignoring the prediction of extreme weather conditions, just for the thrill. The irregularity concerning the weather may dissuade many prospective settlers for the planet; but for two young Zags (the dominant species and part of a small group of permanent inhabitants on Zagworld) – named Morza and Yugnor, this planet is their home.

Morza knows how much predictions can be helpful. Nowadays she listens attentively when a weekly weather forecast is broadcast through their Plasma Screens, a week in advance. Morza knows first-hand how important these predictions are – when she was younger, she ignored the weather prediction for extreme winds, like many Zags in the past, and didn't properly secure her ZagPod. On that day the storm was one of the worst storms in Zagworld's history and the numbers of homeless Zag inhabitants increased enormously. She too became just a statistic, one of many, when her ZagPod was blown away, but fortunately another Zag, called Yugnor, helped her through his charity called Zaghelp.

Not only did she and many others aided by Zaghelp get a new, safe and secure ZagPod home, she also obtained a friend for life. Morza is now also a proud owner of a dessert café called "Zag's Dessert Haven" selling desserts and snacks, ranging from ice-cream based desserts, snacks such as crisps and raisins, to their famous hot chocolate range, which boasts over 20 mouth-watering flavours. Every year Yugnor and Morza organise a Zaghelp fundraising event in order to support the wonderful work of the Zaghelp charity.

"Hey Yugnor!", pondered Morza, as they ambled along a cobblestoned road, with a crisp gust of wind gently drifting some leaves around. "What should I offer on the menu in my dessert café for this year's fundraising day in order to raise as much money as possible for Zaghelp? We typically welcome 150 guests per day, and we already have 150 confirmed guests for that day so I need to plan judiciously which provisions to purchase for the occasion.".

"I've got a spectacular idea! Do you have your sales data for the last 40 days? Why don't we see if we can spot some trends using that data?" responded Yugnor, excitement lighting up his eyes behind heart-shaped glasses. Looking a bit puzzled Morza agreed and, settling down for a bit of rest, they retrieved the data from Morza's iZag, and the two Zags plugged the figures into a table collectively. They had data from 40 days. The first 5 entries looked as follows:

Day	Number of ice-cream based desserts sold	Number of hot chocolates sold	Number of snacks (such as sweets, crisps or raisins) sold
1	85	15	40
2	54	54	61
3	27	70	49
4	79	29	9
5	15	95	15

"The first five days are in a table based on how many of each product we sold. But this data seems so random…just like the weather on our planet! At least the weather can be predicted a week in advance with an extremely high accuracy here!" Morza sighed, losing hope.

"Wait a second! Yes, that's it! The weather! Let's see if there is any correlation between the temperature and the number of each product sold." Yugnor abruptly exclaimed, his hands trembling with anticipation.

"What is correlation, and what does it have to do with temperature?" Morza rubbed her antennae as she wondered what Yugnor was proposing.

"Let me explain! But first, let's find out the temperatures for each of those days and include a column for temperature data in our table." smiled Yugnor, pleased that he could pass on his mathematical knowledge and joy of maths to someone else. The first 5 entries in the table with the additional 'temperature' column now looked as follows:

Day	Temperature(°C)	Number of ice-cream based desserts sold	Number of hot chocolates sold	Number of snacks (such as sweets, crisps or raisins) sold
1	25	85	15	40
2	1	54	54	61
3	-17	27	70	49
4	18	79	29	9
5	-25	15	95	15

"**Correlation** is the statistical term describing the degree to which two variables move in coordination with one another. Essentially, what we are doing is seeing how closely two things are related." Yugnor elaborated, trying to read Morza's reactions to see whether she understood or not.

"Wait, so is a correlation a direct link between how things are related? I think I've thought of a correlation – do you remember what our neighbours told us? They told us that their species in general have more antennae the older they are! Is that a correlation, as there seems to be a direct link between the two variables of age and number of antennae!" Morza reasoned, pleased with herself for thinking of such a great example.

"Yes, that's right, a brilliant example! Remember when a group of Earthlings, or humans as they call themselves, came over with photos of their trees?


There is a correlation between the number of rings in a tree and the age of the tree on their planet!" Yugnor replied, delighted that Morza understood the concept incredibly swiftly.

"But how are we going to see whether there is a correlation between our data? How can we see this correlation when all we have is a table of data? How will that correlation help us? How can I use the correlation to predict how many of each product I would need?" Morza fired the questions at Yugnor with overwhelming speed.

"Woah, woah, woah Morza! One step at a time. Let's plot the data from the table in a scatter graph and see if there is any clear correlation. A scatter graph is the best graph to see correlations between data without 'averaging out' the data, so that we do not overlook or not leave out any outliers in the data." Yugnor responded with delight and slight hesitation, as he was not used to so much enthusiasm about maths. "And before you ask about **outliers** – they are simply data points that do not fit the rest of the pattern, if there is any pattern."

"Let's start with plotting the ice-cream-based desserts. Let's put the temperature on the horizontal X-axis and the number of ice-cream-based desserts sold on the vertical Y-axis. If we use a graph paper on your iZag, we can easily measure out our axis and plot the graph precisely." Yugnor clarified the graph plotting process to Morza.

"Okay, let's start with our first day when the temperature was 25°C, and the number of ice-cream based desserts sold was 85 and the number of hot chocolates sold was 15 and we sold 40 snacks. Now I need to input the data for the next 39 days …" Morza mumbled as she engrossed herself in the task of plotting the graph. The completed graph looked as follows:
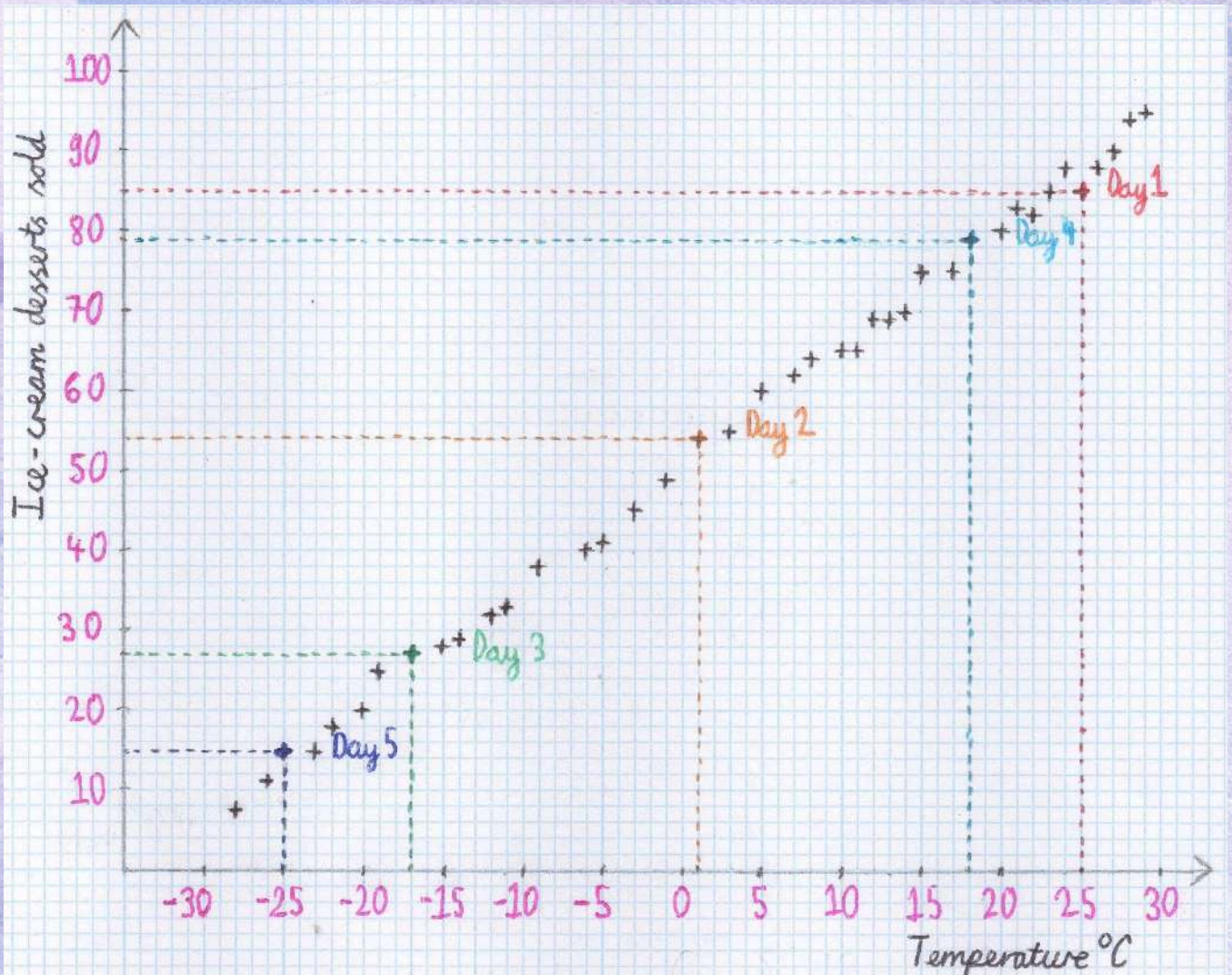
"All done but how can we tell if there is a correlation from this graph?" Morza asked curiously. "Also, is it not curious that the plotted data almost forms a straight line?"

"And if you draw that straight line it will be so called **a line of best fit**, which is simply a line that passes through a scatter graph of data points that best expresses the relationship between those points – you can take an educated guess based on where most of the points are, to see whether a line of best fit is possible." Yugnor replied," Just like this! And here is what our graph looks like now with a line of best fit":
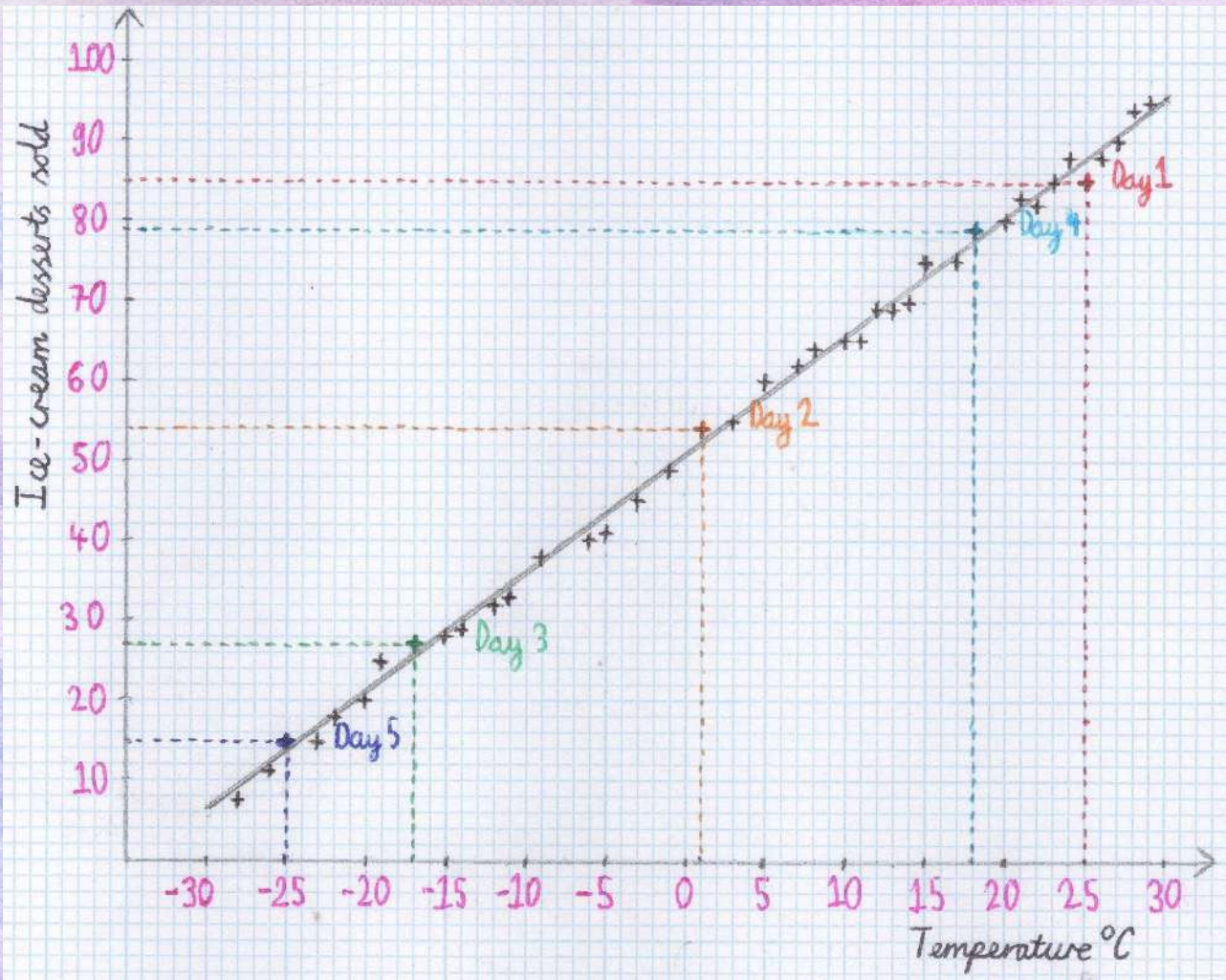

"Ah, yes, the points clearly mark out a line. I can see that the higher the temperature, the more ice-cream-based desserts were sold. Is that the correlation Yugnor?" Morza implored, her antennae ruffled by the gentle breeze.

"Yes, you've beautifully described what the correlation would tell us. But when talking about correlation, we need to talk about the line on the graph to aid our knowledge rather than just talking about the relationship between the temperature and the ice-cream based desserts sold. So, in this case, the higher the temperature, the more ice-cream based desserts sold. As you can see, as the variables on the X-axis (temperature) go up, the variables on the Y-axis (the number of ice-cream-based desserts sold) also goes up. This is known as **a positive correlation**. And as the points are all pretty much next to the line of best fit, this means that this is **a strong, positive correlation**. I memorised this by remembering that a strong correlation is a correlation where the points were ***strongly*** indicating the line of best fit." declared Yugnor, ecstatic to spread his knowledge.

"Now let's plot our range of hot chocolate sales. Again, we must make sure that the temperature is on the horizontal X-axis and the number hot chocolate desserts sold is on the vertical Y-axis. Yugnor encouraged Morza.

Morza plotted the graph much quicker this time – she had more confidence in her own abilities after being guided by Yugnor. "I am going to try to draw the line of best fit as well, but this time the plotted data has not formed a line so clearly, but I tried my best to draw one!" complained Morza. The completed graph looked as follows:
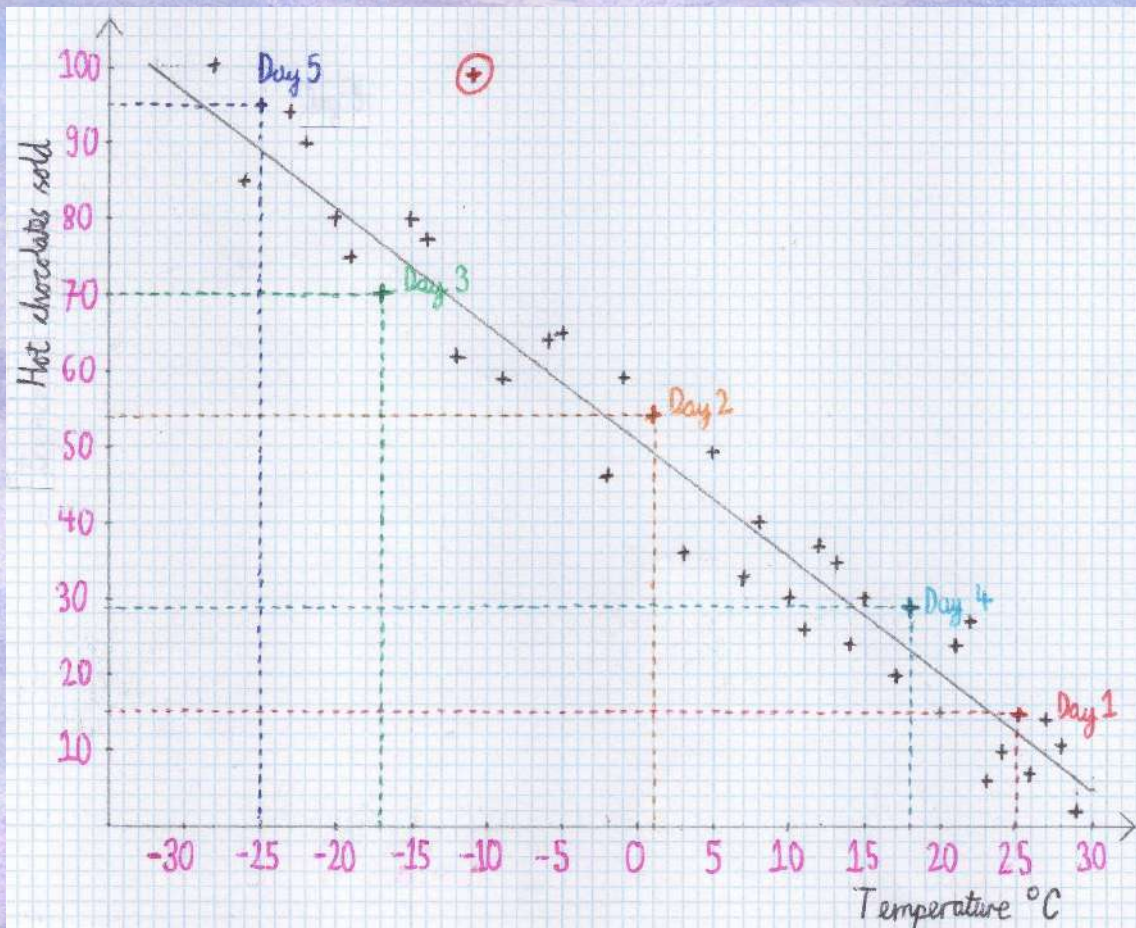
"From this graph I can see that the higher the temperature, the fewer hot chocolates were sold. I don't think it is a positive correlation…what type of correlation is this? Also, it was a bit harder to draw this line of best fit. Although I drew a line of best fit, the points don't line up as well as on the previous graph. In addition, there is this one data point for -11°C that stands out far away from the other data points and the line of best fit. I have marked it red and circled it on my graph. Have I drawn the line of best fit wrongly, Yugnor?" Morza whined, concerned that her line of best fit might not be correct.

"You have done everything correctly. The point that stands out is **an outlier** which I have already told you about. That is simply a data point that does not fit the rest of the pattern which has emerged here. The higher the temperature, the fewer hot chocolates were sold. As the variables on the X-axis (temperature) go up the variables on the Y-axis (the number of hot chocolates sold) go down. This is known as **a negative correlation**. You've drawn the line of best fit absolutely perfectly Morza! That was the exact topic I was going to mention! It wasn't quite as easy to draw the line of best fit as the points marked out a line, but not as clearly as the previous graph – or should we say, not as strongly? The points are all near to the line of best fit, but not exactly as close as the previous graph. This means that this is **a weak, negative correlation**. I can tell that it is a weak correlation as the points are not indicating the line of best fit strongly." Yugnor explained, delighted that his friend was starting to use her initiative to gain a deeper understanding of the topic.

"Okay Yugnor, I'll plot the points for the snacks now! I think that I understand it all now, so I'll try and draw the line of best fit without your help!" Morza explained but then paused for a moment. "Wait…is there a line of best fit even possible for this graph?" asked Morza showing Yugnor the graph which looked as follows:
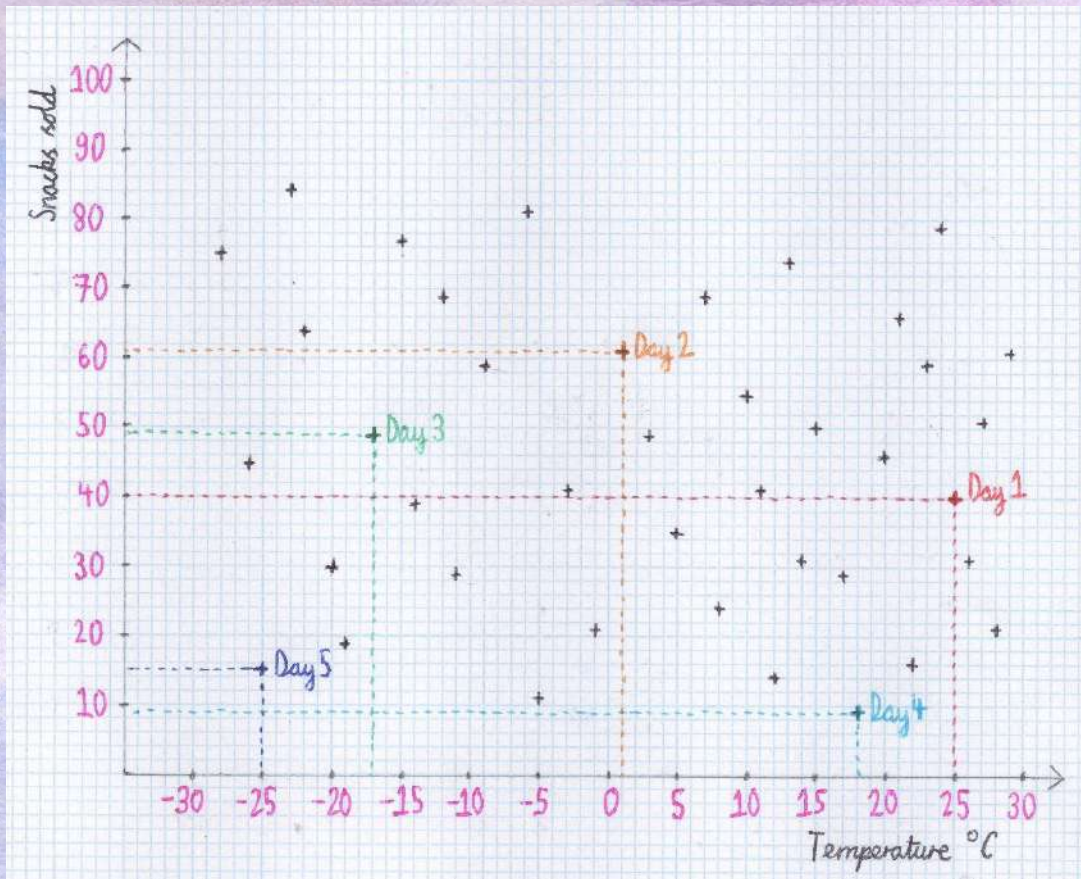
"Well spotted! There is no correlation and we can't draw a line of best fit. Sadly, this means that in terms of snacks, we can't predict how many will be sold on the day of the event…" Yugnor confessed warily.

"Ahh! That's a shame but luckily for us, snacks have long-expiry dates and I always keep plenty of snacks in stock.

"There is one last thing I have to mention before we use the weather forecast to see how to best predict the resources we require – the difference between correlation and causation." Yugnor added.

"Oh, but isn't it enough to just use the correlation of the results to see which products I need to buy to prepare the required estimated number of desserts and hot chocolates? We already know that if the weather forecast states that it will be hot, we should sell lots of ice-cream based desserts and if the weather forecast states that it will be cold, we should sell lots of hot chocolates and in both cases, an unpredictable number of snacks. I don't see what else we need." Morza wondered out loud.

"You are absolutely right but it will be useful for us to at least consider causation. As you know, correlation is a statistical indicator of the relationship between variables, so we know what should sell based on our data and based on the weather forecast prediction. However, we must be careful with correlation as well – if two things are correlated it doesn't necessarily mean a cause-and-effect relationship. Just because it is hot, it doesn't mean that everyone needs to buy ice-cream – some people still will want hot-chocolate and other snacks. This is relevant as we don't need to completely disregard hot chocolate even if it is hot." Yugnor clarified to Morza, propping his heart-shaped glasses up his nose.

"Wait, does this mean that when it's cold it doesn't mean that everybody must buy a hot chocolate and equally when it's hot it doesn't mean that everyone will want to buy an ice-cream based dessert?" Morza asked inquisitively.

"Yes, that's right. Correlation is not causation; it doesn't prove that one thing always causes the other. However, very helpfully it allows us to make assumptions based on the previous data and estimate the sales" Yugnor summarised, leaning forward to have a final look at the data from Morza's iZag.

"The Zaghelp fundraising event is in a week. Let's get the weather forecast Yugnor!" Morza eagerly scrambled for the iZag. "Our weather forecast for the fundraiser is out, precisely a week in advance, as always. OK, looking at the forecast it will be relatively warm. We know that the predicted temperature is 18°C. How should we use the data we have in the scatter graphs to plan what products I should offer in my café? Or is there another mathematical stage that I'm missing that we need to work out, one step at a time, as I am not sure how to use this data?"

"Morza, as you said we've got all the information we could possibly need to make the most efficient choices and prepare the right number of the required products as we have a scatter graph for each type of product, meaning we can make a reasonable prediction about how many we would sell of each dessert based on your previous experiences. Looking at the graphs and lines of best fit we can interpolate the results. Thank the stars that the predicted temperature isn't above or below the range of data that we have, as otherwise we would have to extrapolate which could prove tricky!" Yugnor stated.

"Extrapolate? Interpolate? Yugnor!!!! I thought you said that we already had the information that we could possibly need!!!" Morza jokingly scolded Yugnor.

"Okay, okay Morza! I said that we didn't need any more information for this problem, and your statistics journey has just started!" Yugnor laughed back. "When we have some data, we can reach certain conclusions. For example, one of the points we plotted, we already have the conclusion that on a day when the temperature is 1 °C you sold 54 ice-cream based desserts, 54 hot chocolates and 61 snacks."

"Do you understand? Therefore for 18°C, we would need…" Yugnor trailed off purposefully.

"Oh wait! I can do this! I can just plot a straight line going upwards from the X-axis, specifically above 18°C, and see which number on the Y-axis this corresponds to! Here, let me have a go!" Morza yelped, with exuberant joy of understanding the topic. Yugnor observed Morza and let out a content sigh, pleased that she now understood scatter graphs he could see that his job was done – Morza had interpolated the data correctly estimating that, based on the previously collected sales data on a day when the temperature is 18°C, she will need to prepare at least 79 ice cream desserts and 29 hot chocolates. There was no mathematical means of estimating how many snacks may be sold.

One week after Morza and Yugnor had completed their analysis of the data and planned for the number of products needed, Zag's Dessert Haven was set up for the fundraising for Zaghelp. The pair had painted banners to fly above the café – Morza had been hard at work to ensure that the event would go smoothly. A warm breeze made the Zaghelp banner fly high above the spotted roof of Zag's Dessert Haven; the same breeze also carried a sweet aroma of a numerous number of flavours of Morza's award-winning hot chocolate, filling the air with scents of ginger, mint, rich chocolate, strawberry, and many other exotic and interesting smells to draw the guests in.

Crowds gathered outside the café, creating an aura of excitement. The guests were waiting with pure eagerness bubbling throughout the crowd for Morza and Yugnor to open the fundraising event for Zaghelp.

"Many of you might know me, perhaps a friend introduced you to our café, or you travelled across the galaxy to have a first-hand experience with this award-winning café. But not many of you know my story, which is the reason that our café organises this fundraising event for Zaghelp and the admirable ways in which this worthy charity helps many of us. It was exactly 7 years ago when Storm Taloja caused widespread devastation on Planet Zag. I was left homeless after the storm, but thanks to Yugnor and Zaghelp, many others and I were aided by Zaghelp to get a secure ZagPod home. Thanks to the marvellous work of this charity, I am here today with my own café. But I wouldn't have got here if it were not for the generosity of many, donating money to Zaghelp and other crisis appeal charities. This is why Yugnor and I are here today; to humbly thank you for your support." Morza retold her story, whilst the crowd cheered with awe and support.

"May the 4th Zags Dessert Haven Annual fundraising event for Zaghelp commence!" Yugnor exclaimed, greeted by a roar from the crowd as the café's doors opened.

As the sun set, Morza and Yugnor watched the bustling crowd laugh and enjoy the desserts, the fundraising tin clattered with paper notes and silver coins – the event was a total success, thanks to Yugnor and Morza's mathematical analysis of the data. As the wind rustled their antennae, the pair observed the joyful crowd, then looked at the vivid colours of the sunset, then at each other, and simply smiled, wistfully watching the lavender fields.

Two Zags (the dominant species and part of a small group of permanent inhabitants on Planet Zagworld) are trying to raise money for their local charity, which helps young Zags who are homeless. Morza and Yugnor have 150 confirmed visitors coming to their charity dessert sale. How will they predict what desserts to prepare to appeal to the guests and maximise the number of desserts sold? With the help of scatter graphs and correlation analyses, will they be able to plan a successful fundraising charity event?

ABOUT THE AUTHOR

I am Elleanore Phillips and I am 14 years old. I attend Townley Grammar School in Bexleyheath, England. I enjoy Maths and want to show people that Maths is everywhere, you can't escape it, you need to embrace it. Maths is very useful in life.