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What do people like about mathematics?

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Abstract

In this discussion paper we look at questions that adults have about numbers. Many of their questions are not about pure mathematics, but about personal, cultural or societal issues. We discuss how to connect mathematical topics with things people are interested in, based on theoretic knowledge from the field of science communication. We focus on using narratives to make mathematics more personal, how to use games as demonstrations and different ways to present the same mathematical problem in different societal settings.

Introduction

When I tell people I studied mathematics, the most common responses are 'I was very bad at maths in school' or a plain 'Really? I hate mathematics.' However, when you actually talk to people, it turns out that quite a few of them are in fact quite keen on learning more about mathematics. And adults consistently name mathematics as the school subject with the most value to their lives (Gallup, 2013).

In science communication it is very important to talk with your target group instead of talking about them (Arnstein, 1969). This paper discusses what kind of mathematics the general public is interested in by asking them questions about numbers via mass media.

Let's just ask people what they like

In 2011 the British journalist and mathematician Alex Bellos asked people what their favourite number is (Bellos, 2014). He set up a website where people could send in their favourite and tell him why they liked this number.

Over 44,000 people responded and Bellos reported that the world's favourite number is 7, with 3 and 8 as runners up. Almost half of the submissions were for a number between 1 and 10 and the lowest whole number that did not receive any votes was 110. The most common reason for picking a favourite number was it being a birthday. Even more interesting were the properties that people connected with their favourite numbers: 7 was described as sacred, magical, good, unalterable, overconfident and awkward. While 8 was called neat, feminine, reliable, kind, unassuming and huggable. People seemed to anthropomorphize numbers and ascribe entire personalities to them. This begged for a follow-up question where people could explain more about which numbers matter to them personally.

A broader question

Since 2014 I have been writing a weekly column for the national paper De Volkskrant under the title *Ionica saw a number*. Every week I discuss a number that was somehow in the news, the column can be about anything from politics to literature and from classic math puzzles to recent research. I often get suggestions from readers, or nice additional information about the subjects I wrote about. About a quarter of my columns are inspired by reader's suggestions.

In my 100th column I decided to something similar to what Alex Bellos did: I asked people which number they thought deserved its own column and why (Smeets, 2017). Readers could send in their suggestions by e-mail. I promised to write my 101th column about one of their suggestions.

The response

Within one weekend the question yielded 203 responses from readers. Their suggestions ranged from very funny to very serious. A fun question came from someone who wanted to know if there was anything interesting about the number six, since Bert proclaims in Sesame Street that his favourite number is six and Ernie keeps protesting that six is a very boring number. A more serious question came from a reader who was wondering why the Dutch House of Representatives has 150 seats. Why was this number chosen? Should the number of seats be expanded as the population grows? And do other countries use a similar ratio of representatives compared to the population?

One of the most serious questions, and the one I wrote my next column about, was very personal. A reader wrote about a friend who was in the hospital with leukaemia. To survive he needed stem cell therapy with suitable donor material. For siblings the probability that they are a match is 25%. The friend in the hospital had three siblings and his family and friends were desperately trying to calculate the probability that at least one of them would be a suitable donor. This is mathematics that really matters to people's lives and I explained in my column how to calculate that the probability of at least one match amongst the three siblings is 58%. I also wrote about more general odds of finding a match and encouraged readers to register as donors, since the odds are much lower than you would like.

Categories of responses

As the previous examples show the subjects of the 203 responses varied wildly. We categorised the responses with an inductive method, following the basic principles of grounded theory (Martin et al, 1986). First we coded all of the responses, then we grouped comparable codes in concepts and in the final coding round we combined similar concept in six overarching categories. These categories are:

1. Personal: this category included questions and anecdotes about lucky numbers, special dates and times plus personal connections people felt with a number.
2. Cultural: this category included questions and anecdotes about music, books, language, history and games.
3. Societal: the questions and anecdotes in this category were mainly about why certain numbers in the society are chosen as they are and how the occurrences of societal phenomena are distributed.
4. Mathematical: this category contained nice facts about numbers and theoretical questions about infinity, pi and prime numbers.
5. Scientific: this category was for all questions or stories about biology, physics, astronomy and the other sciences.
6. Other: Everything that could not fit in one of the above categories. For instance because readers only sent in a number without further comment.

Some responses mentioned different numbers or would fit into multiple categories, in those cases we chose the category best fitting the first topic mentioned.

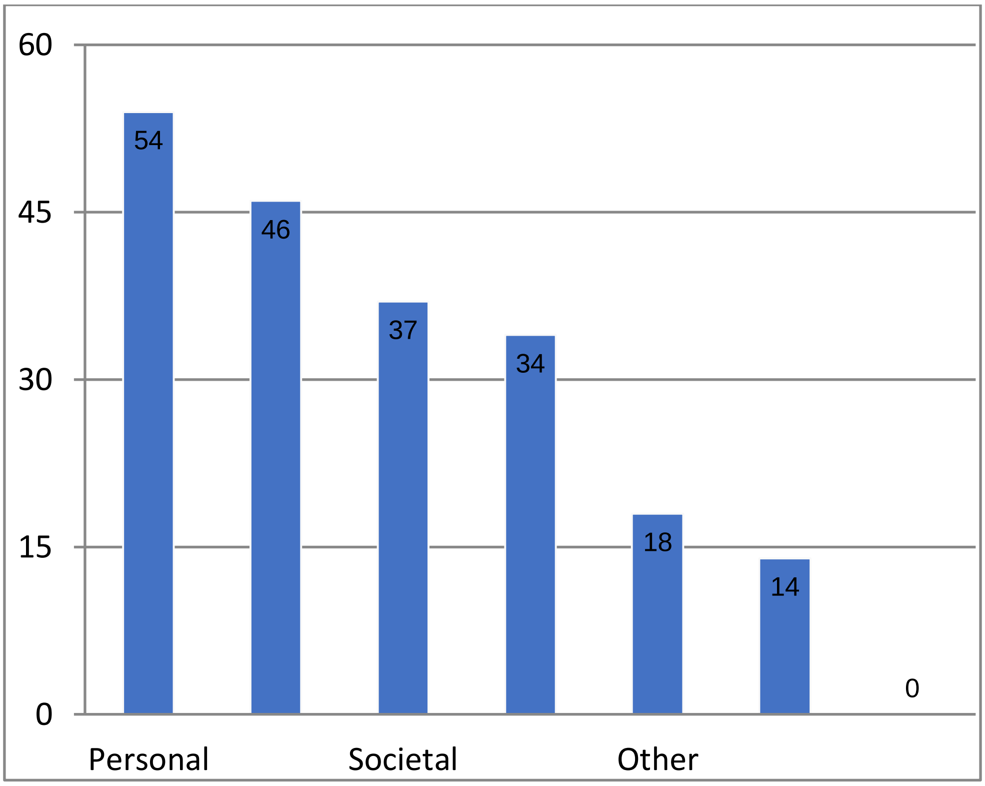

Figure 1. Reader's responses grouped by category

Figure 1 shows the distribution of the readers responses over these six categories. The three biggest categories are Personal, Cultural and Societal questions. In the rest of this paper we will discuss ways to connect people to mathematics using one of these themes.

Personal mathematics

People give numbers personalities and connect personally with a clock time like 22:22. There are many stories behind the numbers. Yet when we present mathematics we too often start from the facts and use a structure where we first introduce a topic, give all the necessary background and definitions, derive the results and only then (if there is still time) talk about why this matters. While science communication literature generally shows that is easier to convince people with stories than with logical arguments (Dahlstrom, 2014).

Telling it like Kurt Vonnegut, one way to make mathematics more personal, is using techniques from storytelling. The American writer Kurt Vonnegut describes how you can build a story based on a simple graph:

> Now let me give you a marketing tip. The people who can afford to buy books and magazines and go to the movies don't like to hear about people who are poor or sick, so start your story up here [indicates top of the Good fortune -Ill fortune axis]. You will see this story over and over again. People love it, and it is not copyrighted. The story is 'Man in Hole,' but the story needn't be about a man or a hole. It's: somebody gets into trouble, gets out of it again [draws a graph]. It is not accidental that the line ends up higher than where it began. This is encouraging to readers.
>
> (VONNEGUT, 2011)

Even the most difficult mathematics can be presented as a story that connects with people. One of the nicest examples I have ever seen was a graduate student who was working on elliptical curves who presented his work as a will-they-make-it-in-time-adventure with a co-author who had to catch a plane to his institute where he would be very hard to reach by e-mail. The entire audience was so eager to hear if they made it, that they happily listened to all kind of details about elliptical curves.

Small tricks from storytelling can be useful to communicate, even within science itself. A recent study showed that scientific papers on climate change that use narrative techniques are cited more often (Hillier, 2016). These basic narrative techniques are relatively easy to incorporate in texts or lectures about mathematics and include using sensory language and using conjunctions to logically order the reasoning. Furthermore making a direct appeal to the audience is a successful narrative tool for helping people understand why what you are telling them is important. You can do this for instance by asking your audience to imagine something or giving them a clear recommendation for action.

Cultural mathematics

There are many ways to connect mathematics to cultural subjects. When you want to introduce fractals you can use the fact that they are used to test the authenticity of Jackson Pollock's drip paintings (Taylor et al, 1999). Or if you have a less high-brow audience you could use the computer-generated backgrounds of animation movies like Up. There's mathematics to be found in popular books and movies and you can use them to engage math-haters.

In this section I am going to focus on another cultural phenomenon: games. Readers sent in many questions and suggestions about numbers in games, so this seems to be something that is on people's minds. In the last few years gamification has proven to be useful in many educational contexts (Hamari et al. 2014). There are many examples of beautiful games in mathematics, here I will focus on a simple version of Nim and the different ways you can present the same game.

Nim

Nim is a game where two players take turns and remove objects from distinct heaps (Berlekamp et al, 1982). In the simplified 21-version there is one heap with 21 objects, in each turn a player can take away 1,2 or 3 objects and the person who has to take the last object loses the game. In this case there is a winning strategy for the second player, which is not too hard to figure out.

In 2006 I played this game with a bunch of mathematicians at a science festival. We played the game with matches on a table and invited the audience to try and beat us. Since we were polite and let the other person start the game, none of them stood a chance. We usually played a few games, until they figured out the strategy for themselves. This worked well and afterwards I used the game in many talks and workshops.

A few years later I was asked to give a maths show for a group of two hundred primary school kids. I wanted to play Nim with them, but realised that the matches on a stage would be very unpractical for such a big audience. We decided to use 21 brightly coloured balloons. One volunteer out of the audience would play against me and instead of removing the balloons we would pop them with a pin while the audience shouted their advice. I used this set-up for many more talks and demonstrations.

After the balloon-game I explained why the volunteer would always lose, even if she was the smartest person in the world. If someone from the audience figured out the strategy, I let them explain it. Otherwise I would urge the audience to consider what happens if it is your turn and there are only five balloons left. Whatever you do, the other player can make sure that in your next turn there is only one balloon left, so you will always lose. After this step we can inductively work back to the starting point with 21 balloons.

Are there more ways to use this same game in an educational setting? Of course there are. Marcus du Sautoy plays a similar game with 13 chocolates and one chili pepper (Du Sautoy, 2011). He keeps playing against opponents until they figure out how to make him eat the chili (he is fair enough to let them start in the position with a winning strategy). This set-up works really well in smaller groups and is great for making participants figuring out the strategy on their own. The take home message is that you should think about the best way to present a game for your audience.

Societal mathematics

In the previous section we saw that there are many ways to present the same game. One of the nice things about mathematics is that you quite often can present the same idea in many different societal settings. It has been shown that personalising mathematics has a positive effect on both learning gain and interest in mathematics (Bernacki et al, 2018). The underlying mathematics stays the same, but it will be much easier for people to relate to an example from a field they are interested in. My favourite paradox can for instance be introduced in many different ways.

Simpsons paradox

If I am presenting Simpsons paradox to an audience of teachers, or other people interested in education, I start with the example of a gender bias case at Berkeley University (Bickel et al, 1975).

Table 1.

Admittance rates of the six biggest departments

Department	Men		Women	
	Applications	Admitted	Applications	Admitted
A	825	62%	108	82%
B	560	63%	25	68%
C	325	37%	593	34%
D	417	33%	375	35%
E	191	28%	393	24%
F	272	6%	341	7%

In 1973 thousands of students applied for admission at Berkeley. Of the 8.442 men who applied, 44% was admitted. Of the 4.321 women who applied, only 35% was admitted. It seems that there is some gender bias, since women have a significantly lower probability of being admitted.However, a closer look at the admission process reveals that each department did their own admissions. Table 1 shows the admittance rates of the six biggest departments.

We see that in most departments women have a higher probability of being admitted than men. This pattern held for the entire university, yet when we look at the total admittance rates, women seem to have a lower probability of being accepted.

In lectures this is the point where I ask the audience to think about explanations. Sometimes people guess that it might be because there are more men applying than women, but this does not explain the odds as they are. Young students usually guess what is happening here: women and men pick different studies. The most popular department for men is A with an overall admittance rate of 64% However, amongst women the most popular department is C with a much lower overall admittance rate of 35%. So even though women have a slightly higher probability of being admitted to a department, in total over the university they have a lower probability of being admitted.

This is Simpson's paradox: A trend in different groups is reversed when the groups are combined. If I am talking to an audience of medical professionals, I introduce the very same paradox with another real-life example. A study compared two treatments on kidney stones: the expensive method A and the cheaper method B. The study found that method A had the best results for patients with small kidney stones. It also found that method A had the best results for patients with large kidney stones. Finally it concluded that averaged over all patients method B was the better one. How is this possible? Once again, the clue is that patients are not randomly distributed over the methods. The patients with small kidney stones usually got method B (and had little complications) while the patients with large kidney stones were given method A (and had more complications, since they came in with a larger problem).

Simpsons paradox pops up in batting averages in baseball, payment gender gaps, survival rates for the Titanic, delayed flights from different carriers and death-penalty sentences. You can probably construct a realistic example of Simpson's paradox for any field of interest to explain the basic idea behind it (Wagner, 1982). This is true for many mathematical concepts: you can translate them to apply to any subject your audience is intrinsically interested in.

Discussion

We described ways to connect people to mathematics, based on the three most occurring categories of suggestions in a small non-random survey of newspaper readers. Their preference for these categories might not generalize to the general population and one could also describe cases on how to connect with a public that is interested in other categories. For instance, when communicating with people who are already interested in mathematical topics it might be good to focus on a more abstract case. A great example of this is a video about infinite sums by YouTube channel Numberphile that currently has over 6 million views and more than 12 thousand comments (Haran et al, 2014). For people interested in the category of broader scientific concepts, it will be useful to consider cases where mathematics leads to applications in other fields. One nice example is Braess' paradox applied to traffic networks, where adding a new road actually impedes the traffic flow (Braess et al, 2005).

However, whichever category of mathematical questions people are interested in, the general science communication theories we describe will apply in these contexts. A broader review of science communication literature can give more advice on the use of jargon and target audiences (Hut et al, 2016).

Conclusions

When people are invited to ask questions about numbers, many of their responses are not about pure mathematics, but about personal, cultural and societal issues. We discussed ways to relate mathematics to these kind of questions to make it easier to connect with people. Remember that you can steal narrative tricks from writers, how games can be a playful way to introduce concepts and that there are many ways to present the same mathematical idea.

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