Testing Murphy's Law: urban myths as a source of school science projects

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Investigating the truth – or otherwise – of urban myths can provide stimulating exercises in the scientific process for both primary and secondary schoolchildren

ABSTRACT

Demonstrations that science and its methods have applications beyond the laboratory form a crucial part of any scientific education. The investigation of urban myths can provide a rich source of stimulating projects demonstrating the uses of the scientific method beyond its usual settings. This article discusses the specific case of Murphy's Law of Toast, the urban myth that states: 'If toast can land butter-side down, it will do'. Investigating the truth – or otherwise – of this notorious alleged phenomenon was the basis of a nationwide schools science project conducted by the author in collaboration with the Department for Education and Employment and a commercial sponsor. The project motivated discussion and use of key scientific processes, and inspired many pupils to go beyond the prescribed experiments, testing their own hypotheses. Other urban myths suitable for similar investigations are discussed.

A major challenge for any science teacher is to show the relevance of what is being taught to everyday life. Unless scientific principles are seen to be relevant and useful beyond the confines of the laboratory and the examination syllabus, pupils can come to regard science as an esoteric irrelevance.

Good science teachers routinely try to link abstract principles such as Newton's Third Law of Motion to everyday examples, such as the back-reaction of a boat as one disembarks on to shore. Yet such examples are often trite and uninspiring. Worse still, they often fail to show that the principles of science have applications outside 'scientific' settings. For example, while Pascal's Law of Pressure can be illustrated via the brake pedal of a sports-car and Bernoulli's Principle by an aircraft wing, both examples are drawn from technological settings where the application of science comes as little surprise.

In what follows, I show how urban myths can serve as the basis of scientific projects requiring the use of scientific principles outside their usual setting. By using the 'tool kit' of science to investigate urban myths, pupils can acquire a sense of the everyday use and importance of the principles they are being taught.

As a case-study, I focus on Murphy's Law of Toast, which states that 'If toast can land butter-side down on the floor, making the maximum amount of mess, it will do'. As an urban myth suitable for a school science project, Murphy's Law of Toast has four key features:

- It is a well-known urban myth (the first reference to it was made in a poem by James Payn in 1884), yet despite widespread belief in its validity, scientific opinion has tended to be sceptical (for reviews, see Matthews, 1997a, 1999).
- Several potential explanations suggest themselves, ranging from the sceptical (selective memory of just the 50% of falls ending in butter-down landings) to the deterministic (the weight of the butter on one side guarantees 100% butter-down landings).
- Experiments to test these explanations are simple, safe and inexpensive: just a plate, toast and butter/spread are required.
- Data collection and analysis are straightforward.

Background to the tumbling toast project

In June 2000, representatives of Arla Foods, manufacturers of Lurpak butter, asked me to design an educational project based around Murphy's Law of Toast. My involvement came about as the result of publishing a paper in the *European Journal of Physics* in 1995, which analysed the dynamics of toast tumbling off a plate (Matthews, 1995). Using a simple rigid-body model, I showed there were good grounds for believing Murphy's Law of Toast to be valid. The explanation lies in the size of the torque induced in the toast as it slides off a carelessly-held plate. As the toast loses contact with the plate almost immediately after its centre of gravity passes over the edge of the plate, the resulting spin-rate is very low – so low, indeed, that theory predicts that toast dropped from waist height has insufficient time to come butter-side up again before striking the floor. The result is a butter-down landing, and yet another confirmation of Murphy's Law.

Simple modelling also suggested that – contrary to widespread opinion – the effect of the weight or aerodynamical effect of the butter is negligible to first order. The most important factor is height of drop, giving the toast enough free-fall time to come butter-side up again; theory suggests that toast falling from around 2.5 to 3 metres has a reasonable chance of landing butter-up.

I suggested to the sponsors that these theoretical results might form the basis of a nationwide project for schoolchildren. In collaboration with the *Count On* initiative of the Department for Education and Employment, two studies were set up, tailored to the abilities of primary and secondary school pupils respectively.

Project design

In both cases, the aim of the study was to encourage pupils to think about the plausibility of the 'urban myth', discuss why they reached the beliefs they did, and then use scientific methods to put these beliefs to the test. To stimulate interest and debate, the author prepared a number of web pages about Murphy's Law in general, and the Law of Toast in particular, for *The Sum*, the web-based newspaper of *Count On* (see References). These described how scientists often dismissed such urban myths, with a BBC-TV experiment performed in 1991 apparently 'disproving' Murphy's Law. The web pages also described the existence of possible arguments in favour of Murphy's Law, while emphasising that the ultimate verdict could only emerge from a well-designed experiment. The website gave details of what experiments could cast light on both the reality of Murphy's Law, and – if true – its likely cause.

To investigate the reality of the effect, all school pupils were asked to place normally-buttered toast on to plates held at waist height and then to tilt the plates until the toast slid off and landed on the floor (which, for reasons of safety and convenience, was to be covered with old newspaper). This procedure was to be repeated 20 times, and the outcome recorded as either butter-down or butter-up. The question of appropriate trial size naturally prompts discussion of two important statistical issues. The first is the need to gather sufficient experimental evidence to reach a result unlikely to be explicable by fluke. Secondly, it raises the issue of statistical power – that is, the sample size required to give a reasonable chance of revealing a genuine effect, if one exists.

This latter issue is of particular relevance for studies of urban myths. For if the effect being sought is so weak that its existence is revealed only after many trials, then it is unlikely to be the effect underpinning the urban myth, as it cannot explain why so many people claim to have witnessed the phenomenon. In the case of Murphy's Law of Toast, for example, if there is a bias towards butter-down landings, it is reasonable to assume that this bias will reveal itself after 20 trials or so; hence the use of this figure as the typical trial size.

Having investigated the reality of the effect, pupils were then asked to investigate possible explanations. If the first part of the experiment had revealed no obvious bias towards butter-down landings, then selective memory is one obvious candidate. If a bias was found, however, pupils were then asked to investigate the oft-cited effect of the presence of the butter on one side. To do this, a second piece of toast was to be taken, and a letter 'B' – for 'butter' – written on one side with a marker pen. The toast was then to be allowed to slide off the plate 20 times as before, and the outcome noted.

In addition to these two tests, secondary school pupils were given a third task, designed to investigate the author's claim that height was the crucial factor in determining butter-down landings. To do this, pupils were asked to repeat the first experiment, but this time from a height of 2.5 metres.

Once completed, pupils were asked to report their results via the special web-based reporting page on *The Sum* website. They were also asked to include any comments about what they found, and their explanations of their results, together with any ideas they had for circumventing Murphy's Law and preventing toast landing butter-side down.

The results

The Lurpak Tumbling Toast Test was officially launched in March 2001 (generating considerable media attention in the process), and schools were given eight weeks to perform the tests and report their findings.

A total of just over 1000 schoolchildren (70% primary, 30% secondary) from schools across the UK took part in the three experiments, performing a total of over 21 000 drops of toast. The dedication of some of the school teams was impressive, with 22 reporting at least 100 drops, 10 at least 400 drops, and two conducting over 1000. The overall results of the three basic experiments were as follows:

(a) *Does buttered toast tend to land butter-down?*

Out of a total of 9821 drops, there were 6101 butter-down landings, a rate of 62%, which is 12% higher than the 50% rate expected if – as many scientists have claimed – toast is as likely to land butter-up as down, and its final state is random.

(b) *Is butter the cause of butter-down landings?*

Out of a total of 9748 drops of toast marked only with a 'B', there were 5663 B-side-down landings, giving a rate of 58%, which is only 4% less than the rate for buttered toast.

(c) *Is height the cause of butter-down landings?*

Out of a total of 2038 drops of toast from 2.5 metres, there were 953 butter-down landings, an overall rate of 47%, which is 3% *lower* than the 50:50 random rate.

Analysis and implications

The interpretation of these results naturally stimulates discussion of key statistical concepts such as formulation of null hypotheses, *p*-values and statistical versus practical significance. For example, the 62% rate found for the basic buttered toast experiment appears to confirm Murphy's Law of Tumbling Toast, but how convincingly? What are the chances of getting at least as impressive a deviation from the 50:50 split by fluke alone? Similarly, the results from the experiment with toast marked with a 'B', gave a B-side down rate somewhat lower than that for buttered toast, but still higher than the 50% random rate. Were these differences statistically and/or practically significant, and do they confirm theoretical expectation that butter is not the prime culprit in butter-down landings? Finally, the results from the 2.5 metre drop-height experiment showed a butter-down rate somewhat *lower* than the 50% rate expected by chance alone. Again, were the differences statistically and/or practically significant, and do they confirm that drop-height is the principal determinant of butter-down landings?

Such questions can be addressed by the formulation of appropriate null hypotheses (in the present case, that the toast is as likely to land butter-up as butter-down) and calculation of *p*-values (i.e. the probability of getting at least as big a difference from the prediction of the null hypothesis, assuming this null hypothesis is true). Those seeking more general background on such analysis can find it in any introductory statistics text (e.g. Freedman, Pisani, and Purves, 1998). An analysis for the results presented here is given on the *Count On* website (see References). For example, the rate of B-side down landings turns out to be both substantially, and statistically significantly, different from the 50% chance value, with an extremely low *p*-value of $\sim 10^{-57}$. This confirms the theoretical expectation that, contrary to popular belief, the presence of butter cannot explain Murphy's Law of Toast: even in its absence, toast still has a considerable bias towards face-down landings. Similarly, the above results show that the sub-50% rate of butter-down landings of toast falling from 2.5 metres is statistically significant, with a *p*-value of 0.003, consistent with theoretical expectation that height has a genuine effect on the fate of tumbling toast.

Do the results support the urban myth?

As said earlier, investigations into urban myths must do more than simply show that an effect exists: they must also show that the effect is strong enough to reveal itself in relatively few trials. If this is not so, then the effect found cannot plausibly be taken to explain the urban myth, as the effect is unlikely to have been noticed by people in the course of everyday life.

Thus, at the conclusion to any investigation of an urban myth, one should use the various data-sets obtained by pupils to estimate the number of trials needed to reveal the existence of the effect. This amounts to a power calculation; standard statistical theory shows that the number of trials, N, needed to reveal a statistically significant effect with 80% reliability is $N = (2.8/d)^2$, where d is the so-called effect size, defined as the difference between the mean value found by the studies and that predicted by the null hypothesis, divided by the standard deviation. In the case of Murphy's Law of Toast, the 74 sets of data reported by the various schools gave a mean butter-down rate of 64%, with a standard deviation of 19%; the effect size is thus $d = (64 - 50)/19 = 0.74$, so that $N \sim 14$. Thus the effect found in the tumbling toast project is so strong that it will become apparent to anyone who witnesses more than a dozen or so examples of toast tumbling to the ground. This is sufficiently small to justify the claim that the project has not only confirmed the existence of a bias towards butter-down landings, but has also shown that this bias is large enough to account for the persistence of the urban myth.

Conclusions

The aim of the project reported here was to encourage both primary and secondary pupils to discover that science and the scientific method is relevant to everyday phenomena. In this respect at least, the tumbling toast project was a success: with over 1000 pupils taking part across the UK, it is the largest-ever systematic study of Murphy's Law of Toast. It also showed conclusively that the Law is *not* an urban myth: toast sliding off a plate under natural conditions really does have a substantial bias towards butter-down landings. As such, the schoolchildren taking part have convincingly refuted the view of many 'experts' that butter-down landings are no more likely than butter-up, and that Murphy's Law of Toast is merely the product of selective memory for unfortunate outcomes. The results presented here also contradict the conclusions of a far smaller but well-publicised study of Murphy's Law of Toast by the BBC1 programme *QED*, broadcast in 1991. This failed to find any evidence for the law in various experiments involving 300 tosses of buttered bread. This was entirely to be expected, however, as tossing bread is dynamically quite different from allowing toast to

slide off a plate, is essentially identical to a coin-toss, and is of no relevance to the real-life situation.

Those taking part in the tumbling toast project did more than simply confirm the existence of the tumbling toast effect. They also showed that, contrary to popular belief, the presence of butter on the toast makes little practical difference to the outcome of the landing. This is in accordance with theoretical estimates of the likely mass asymmetry and aerodynamic effect of the thin layer of butter. Butter-down landings were, however, shown to be substantially related to height of drop. When dropped from 2.5 metres up, the toast was much more likely than toast dropped from waist height to land butter-side up.

Comments received from teachers and pupils via the *Count On* website and directly suggest the project served its purpose in provoking discussion about scientific procedures. For example, younger pupils were sometimes observed ignoring 'incorrect' results, or deliberately flipping the toast to get what they thought was the 'right' answer. This prompted valuable discussion about the purpose of experiments being not to confirm expectations (which may be misplaced), but to establish the truth. Many pupils clearly saw how to use the same scientific procedures to go further, and investigate possible remedies for Murphy's Law. Suggestions made by pupils included putting toast butter-side down on plates before moving from the toaster to the table, and carrying plates high above the head; many pupils supplied extra data to support their claims.

The success of the Murphy's Law of Toast project suggests that it could form the prototype for others, in which well-known urban myths are examined and their veracity – or otherwise – investigated experimentally. Other urban myths amenable to such investigations include:

- Water draining from a basin swirls anti-clockwise in the Northern hemisphere (and clockwise in the Antipodes – a project thus offering opportunities for Internet-based global cooperation).
- If you're looking for somewhere in a road atlas, it will usually lie in the awkward part of the map, close to the edges or down the central crease.
- The neighbouring supermarket queue usually finishes first.
- Soaking conkers in vinegar makes them harder.
- A bottle of fizzy drink with a spoon in its neck keeps fizzy longer.

- Watering plants on a hot day burns them, through the lensing effect of water droplets.
- Adding cold milk immediately to a hot drink keeps it warmer for longer.
- Dangling a chain from the back of a car protects against car-sickness.
- Hot drinks are better at keeping you cool in hot weather than cold drinks.
- Eating chocolate causes spots.

As I have indicated, such projects can motivate discussion of a wide range of scientific issues:

- Whether there are any plausible explanations of the claim.
- The need for an appropriate experimental design to test these explanations.
- Establishing an appropriate number of trials.
- Collecting and recording data carefully and impartially.
- Analysing and interpreting the data: setting up null hypotheses; performing significance tests; assessing practical significance.

As in the case-study examined here, the methods used and results could be posted on the World-Wide Web, with a view to encouraging other schools, science clubs or individuals to contribute their own data; the author would be happy to hear from anyone wishing to do this.

The key issue highlighted by such projects is, however, the applicability of the methods of science to issues of everyday experience. By focusing on phenomena dismissed as myths by experts, such projects show that science allows everyone to find out the truth for themselves. Certainly, some of the supposed 'myths' suggested above have apparently plausible explanations: the cases of water swirling out of basins, road atlases and supermarket queues all have strong theoretical foundations, but of varying relevance to real-life situations (Trefethen *et al.*, 1965; Matthews, 1997b, 2000). Others, such as water droplets burning plants and chains combating car sickness, have a much more questionable scientific basis.

In every case, however, the truth is out there, and I hope teachers and pupils alike have as much fun uncovering it as I did with tumbling toast.

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