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Modelling Zombies and Other Diseases

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ABSTRACT

Technocamps[1] is a national outreach programme based at Swansea University which – amongst many other things – provides STEM-based workshops to schools and young people. Before 2020, one popular set of Technocamps computational thinking workshops was on modelling the spread of diseases, which for our audience was a zombie infection. These workshops were all *unplugged* in nature and involved spreading diseases by passing around tokens. Different numbers of tokens were passed about, representing the ability of the disease to spread; and participants might be vaccinated giving them immunity. By changing such factors, the young people could watch how the disease might overcome the class or might die out. These workshops were particularly popular when presented in conjunction with the Royal Institution's Christmas Lectures – a series of popular lectures to young people – in December 2019 which were on understanding probability. Little did we know that our workshop series would take on a frighteningly real purpose a few months later. Throughout the COVID-19 pandemic, the public has been bombarded with messages about how governments were "following the science" and presented with images which "model the spread of the virus" and "track the R-value" in different regions of the world. Independent of our outreach activities, we developed visualization tools for public – and government – understanding of the science which we adapted into our outreach workshops. In this paper, we reflect on the effect of these workshops in explaining to young people the power of computational thinking in modelling diseases, and the extent to which they gained an understanding of this and of the current pandemic.

KEYWORDS

Computational thinking, modelling, pandemics, visualization, public understanding, outreach.

1. INTRODUCTION

The mathematical modelling of the spread of infectious diseases – e.g., HIV, influenza, or any number of tropical diseases – has long been of paramount importance. Public understanding of the field and its importance has historically been lacking, due in part to its success: whilst scientists have long been warning of the inevitability of global pandemics, by careful tracking and containment, infectious diseases have rarely progressed beyond the local endemic stage, and thus have stayed out of the public's attention.

There is one form of infectious disease, however, with which people in general have an obsession: zombieism. The 1968 film *The Night of the Living Dead* has cult status and continued popularity. It was already preceded by many such films, dating back at least to 1932's *White Zombie*, and zombies on screen retain a morbid appeal across the world's nations and cultures.

An article in *National Geographic* (Schriber, 2009) on the mathematical modelling of zombies being carried out by Canadian scientists (Munz et al, 2009) created a virus of its own. Within a week of publication, virtually every major news outlet in the world had picked up the story. Since then, there have been volumes of scientific articles devoted to the mathematical modelling of zombies (e.g., Smith, 2014).

Within a national school outreach programme, Technocamps, we deliver engaging workshops which develop young people's understanding of computational thinking as underpinning all STEM subjects. Our workshops are delivered to children of all ages and are typically unplugged. Modelling zombies has for some time been a popular topic for understanding mathematical modelling and in particular its computational aspects. The young people were learning by stealth something which they might never had imagined has real-world relevance, as they of course know that zombies are fiction. But in 2020, the COVID-19 pandemic suddenly made these workshops all too real.

Suddenly, the general public – and politicians – needed to know about and understand the science behind the mathematical modelling of COVID-19 and all of its variants. Within our scientific research programme, we developed a visualization tool which provides a simple interface for novice users to explore the spread of infectious diseases, in particular COVID-19. As it was intended to inform and be used by the general public, the tool was ideally suited to be adapted for use within our school workshops as an implementation of the unplugged activities.

In this paper, we describe the workshop that we have developed, both the unplugged activities and the use of the visualization tool; and provide an evaluation of its effectiveness as measured by feedback from the participants in the pilot sessions that have been carried out during its development. We conclude with a consideration of related work.

[1] technocamps.ac.uk

2. BACKGROUND

2.1. *Technocamps*

Technocamps is a universities-based national schools and community outreach programme. It was founded at Swansea University in 2003, as a re-branding of the successful ITWales programme founded in 1993, but has since expanded to include a hub in every university in Wales. Its mission is to research, champion and deliver change in national curricula, qualifications, delivery, and professional development in order to foster a sustainable digital skills pipeline in Wales (Moller and Crick, 2018). It leads on national programmes of engagements in Wales with both primary and secondary school pupils and teachers, as well as adult learners through its Institute of Coding in Wales digital degree apprenticeship and micro-credential programmes.

A core Technocamps outreach activity is with school children. Since 2011, the programme has engaged with over 65,000 young people across Wales – roughly 7% of the Welsh population today aged 5-24, providing them with hands-on computational thinking workshops delivered in a fun, interactive and thought-provoking style that develops their intuitive understanding of the topics being delivered. Technocamps have developed and delivered a plethora of STEM-based workshops, covering a wide assortment of topics, ranging from the scientific (e.g., *Modelling Molecules*) through the social (e.g., *Technology, Ethics, and the Future*).

An important aspect of Technocamps is its support of teachers across Wales who are charged with teaching computational and digital technology subjects in school, given that only a quarter of them have any background in the subject (Moller & Powell, 2019). This has been made particularly challenging with the COVID-19 pandemic forcing teaching to be on-line and home-based. This has had a huge impact on children and their learning, which has motivated us to use the situation as a learning vehicle, not least to help children gain understanding of their “new normal”.

2.2. Visualisation Research

The visualisation approach used within the workshops arises from a project led by visualisation and epidemiology researchers from Swansea University and the University of Warwick[2], as well as collaborations developed through the Scottish COVID-19 Response Consortium[3] (Chen et al, 2022). In addition to developing visual analytics methods for experts in analysing large collections of contact tracing networks, our aims include developing methods for the communication of disease models to broader audiences in transparent, comprehensive, and engaging ways. The visualisation tool that was used to facilitate the workshops discussed in this paper were driven by this latter ambition.

The design and development of the visualisation tool have been informed by a two-year collaboration. We started by exploring how computational simulations of disease progression could be visually analysed to improve the simulations, and to assess different contact-tracing strategies (Sondag et al, 2022). As expected, these computational epidemiological models are complex and involve several parameters which makes it challenging to communicate their results to broader audiences. We thus developed a web-based, agent-based simulator based on a simpler model that approximates this behaviour[4], as well as an accompanying interactive visualisation framework to be used in engagement and training activities[5]. The visualisation tool described in this paper is a case study where the web-based simulator and the visualisation framework have been applied within the context of disease progression through contact.

3. THE ZOMBIE WORKSHOP

As with most of our workshops, the infectious disease modelling workshop is designed to be delivered within a classroom-style environment, to 25-30 young people aged between 8 to 16, over the course of a morning or an afternoon. To make it lively and engaging, the premise of the workshop is a zombie outbreak that is spreading amongst the participants of the workshop.

The workshop incorporates three modes of delivery. Firstly, a standard presentation style with multimedia resources is used to convey information and engage the participants in discussion. Then a series of unplugged activities are carried out to help participants understand the ways in which infectious diseases spread, and how their spread can be modelled computationally. Finally, a visualization tool is introduced with which the participants can interact in order to understand how different infection rates and varying preventive measures affect the spread of the disease.

3.1. Unplugged Activities

The workshop begins by introducing the concept of *state* in order to track the zombie infestation as it propagates through the classroom. We start with two basic states: a green state to represent an uninfected member of the class; and a purple state to represent an infected member of the class; i.e., the zombies. We then introduce the notion of a simple contagion *process* whereby, at any given point in time, an infected member of the class can infect a nearby classmate.

Figure 1. A Workshop in Action

[2] contact-viz.cim.warwick.ac.uk

[3] www.gla.ac.uk/research/az/scrc

[4] gjmcn.github.io/atomic-agents

[5] gjmcn.github.io/atomic-agents-vis

This forms the basis of our first unplugged activity. Using string to represent connections between two participants, and the flip of a coin to decide whether a zombie infects a neighbouring participant, the class tracks the spread of the zombie apocalypse. In some scenarios, the whole class becomes infected almost immediately; and in others, the zombies take much longer to infect everyone. The string is useful for investigating the history of an infection, from one infected person back to "patient zero".

This first activity inevitably raises several important questions about the spread of diseases. Can a person recover from the disease? Can a person die from the disease? Is there any known vaccination against the disease? With these questions in mind, new states are introduced: a blue state to represent a member of the class who has recovered from or is immune to the disease; and a yellow state to represent a zombie that has died. The participants then re-run the process and notice the differences that these new states create, as well as the added complexity of tracking them.

After exploring this on paper and trialing it several times in animated form, attention is brought to the idea of how this could be a way of understanding how real-life infectious diseases spread in the real world. It is quickly agreed that you would need to be able to track the state of each participant – which even with a small number is quite complex – and that you would need a lot more participants. The conversation is turned towards using a computer to do this, which is when the visualization tool is introduced.

3.2. *Visualization Tool*

The visualization tool we devised provides a simple interface for participants to explore the spread of an infectious disease, using a similar style to those introduced in the unplugged activities. The ability to quickly run simulations and understand the effects of manipulating the probabilities of infection and other parameters provides understanding of how infectious diseases spread and how a computational model can be used to predict their spread.

The simulation is first explained to the participants so that they can associate it with the unplugged activities they have just completed. Each person is represented by a dot within the model. Each dot has a particular state that is represented by a color: light blue meaning healthy; red meaning sick; dark-blue meaning recovered; and yellow meaning dead. The model also introduces the concept of *exposure radius* – the distance at which dots will spread the disease to – which is represented by light grey circles.

Initially, participants are challenged to run the simulation using default settings and investigate the different outcomes produced by running the model several times. This is an important step for participants to reinforce the randomness of these simulations, noting that the simulations will run and evolve differently each time.

Additional functionality of the tool is then explained to the participants, bit-by-bit. Different simulation parameters are explained which can be tweaked in order to affect the speed and effectiveness of the spreading of the infectious disease. These are: the probability that a dot becomes sick when exposed; the probability that a dot recovers or dies; and the exposure radius.

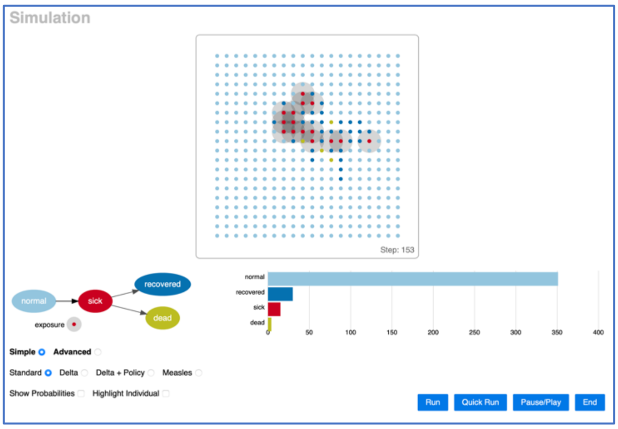

Figure 2. The Visualization Tool. Participants see an infectious disease spread by noting the changing of states (colours) of the dots (people). There is a model diagram explaining the state changes, and a bar chart showing the number in each state at any given time.

Such parameters are associated with every infectious disease. Users can set these parameters themselves or opt for pre-set parameters for existing diseases – e.g., for various COVID variants or for measles – and consider the relative dangers of different diseases. By playing around with different scenarios, participants gain an understanding of the direct link between the model and the COVID-19 pandemic.

The tool then allows for further explorations in which vaccinations can be introduced, and the movement of the dots can be restricted to between home and school or office, or even totally restricted to represent a lockdown scenario. Future developments involve representations of interventions relating to social distancing, social bubbles, and limits on social gatherings; as well as the effect of varying degrees of adherence by the public on such restrictions, in order to explore the effect of people not obeying social distancing and other rules and guidelines that are introduced by their government.

4. EVALUATION

Pilot workshops were delivered to 140 young people from the ages of 9 to 15, in both classrooms and in science festivals. Data was collected from participants using pre-and post-workshop questionnaires that were completed on the day of the workshop. Quantitative data was collected using a 5-point Likert scale and qualitative data by providing participants with an open space to provide their answers.

During the pre-questionnaire, we asked participants to rate and comment on their understanding of how different diseases spread. Of the 137 participants that answered this question, 91 (66%) rated their understanding as nothing (1) to unsure (3). The qualitative data showed a clear trend of participants associating coughing, sneezing and close contact as the primary cause of a disease spreading. In the post-questionnaire, when asked about how much they had learnt about how different diseases spread, of the 123 participants that answered this question, 99 (80%) rated that they had learnt somewhat (4) to a lot (5).

We also evaluated the delivery method of the workshop and asked participants which part of the workshop they felt that they learnt the most from: the presentation, the physical (unplugged) activities, or the visualization tool. Although not the initial intention, a number (30) of participants selected more than one choice. These have been coded against both choices in the table in Figure 3.

	Presentation	Physical Activities	Visualization Tool
All	36	33	63
Aged 9-10	17	14	33
Aged 11-15	19	19	30

Figure 3. Feedback on Effective Learning Modes

Whilst the unplugged activities were clearly appreciated and made the workshops engaging, the use of the visualization tool was clearly what the participants felt they learnt the most from. Initially, based on feedback from initial workshops held at a science festival, we had predicted that younger students would prefer and gain more from the unplugged activities in comparison to the use of the visualization tool; however, this did not turn out to be the case with the school-based workshops. The reason for this, we presume, is due to our own refinement of how the tool is presented and used in the workshops, which evolved from the early science festival presentations in which the visualization tool was used as an add-on to our established fun and engaging interactive workshop.

5. CONCLUSIONS AND RELATED WORK

School children have been hugely affected by the COVID-19 pandemic, and engaging with them in workshops which directly address the cause of the pandemic is warranted. There is evidence that greater knowledge and understanding by young people of infectious diseases leads to more positive attitudes and healthier behaviour (Myant & Williams, 2005). Efforts have been made to impart onto young people understanding of the *biology* of viruses, and in particular COVID-19 (Manches & Ainsworth, 2022). Our efforts are aimed at providing an understanding of the mathematical and computational modelling of COVID-19 and related infections, as these are the bases of the messages they receive and which directly affect their expected behaviour.

Interactive visualisations have previously been developed for similar purposes, an example being the interactive model provided by Stanford University (Childs et al, 2020). Our aim has been to simplify the assumptions and make our visualisations graphically appealing to young people in order to fully engage them.

Another common way to be engaging is through gamification. For example, in the *Can You Save The World* game (Wiseman & Martin, 2020), players gain or lose points depending on their behaviour whilst walking around a virtual environment. This is particularly suited to younger children, but lacks the scope for understanding the effect on whole communities. Our approach is to embody this gamification in our physical unplugged activities, which we find more effective than – and at least as fun as – employing a single-player on-line game.

6. REFERENCES

Chen, M., Abdul-Rahman, A., Archambault, D., Dykes, J , Slingsby, A. , Rtisos, P. D., Torsney-Weir, T., Turkay, C., Bach, B., Borgo, R., Brett, A., Fang, H., Jianu, R. , Khan, S., Laramee, R. S., Nguyen, P. H., Reeve, R., Roberts, J., Vidal, F., Wang, Q., Wood, J., & Xu, K. (2022). RAMPVIS: Answering the Challenges of Building Visualisation Capabilities for Large-scale Emergency Responses. *Epidemics*.

Childs, M., Kain, M., Kirk, D., Harris, M., Ritchie, J., Couper, L., Delwel, I., Nova, N., & Morecai, E. (2020). Potential Long-Term Intervention Strategies for COVID-19. Available at: http://covid-measures.stanford.edu (Accessed May 2, 2022.)

Manches, A., & Ainsworth, S. (2022). Learning About Viruses: Representing COVID-19. *Frontiers in Education, Volume 6*:736744.

Moller, F., & Crick, T. (2018). A University-based Model for Supporting Computer Science Curriculum Reform. *Journal of Computers in Education* 5:415-434.

Moller F, & Powell, S. (2019). Technoteach: Supporting Computing Teachers Across Wales. *Proceedings of WiPSCE'19: the 14th Workshop in Primary and Secondary Computing Education*, Article No. 9, ACM Press.

Munz, P., Hudea, I., Imad, J., & Smith, R. (2009). When zombies attack: Mathematical modelling of an outbreak of zombie infection. In *Infectious Disease Modelling Research Progress*, J.M. Tchuenche & C. Chiyaka (eds), Nova Science, Happuage, NY, 133-156.

Myant, K. A., & Williams, J. M. (2005). Children's Concepts of Health and Illness: Understanding of Contagious Illnesses, Non-contagious Illnesses and Injuries. J. Health Psychol. 10 (6), 805–819.

Scriber, B. (2009). What Can Zombies Teach Us About Swine Flu? *National Geographic,* 12 August 2009.

Smith, R. (2014). *Mathematical Modelling of Zombies.* University of Ottawa Press.

Sondag, M., Turkay, C., Xu, K., Matthews, L., Mohr S., & Archambault D. (2022). Visual Analytics of Contact Tracing Policy Simulations During an Emergency Response, *Computer Graphics Forum*.

Wiseman, R., & Martin, J. (2020). Can You Save the World? Available at: https://martin-jacob.itch.io/can-you-save-the-world (Retrieved May 5th, 2021).