Development of a computational framework to bring added colour and motion to the Irish primary school curriculum

Undergraduate Summer Research Project Report

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1 Introduction

1.1 Aims

Our aim is to implement a computational framework into a series of lessons which will add color and motion to the Primary School Mathematics curriculum. The curriculum has been in place since 1999 and will be replaced by a new curriculum which is expected to be implemented in 2022. Using a computer to perform mathematics and model mathematical situations is an area that we feel students should gain early exposure to. For these reasons we have incorporated Scratch, Geogebra and Python into our lessons. In accordance with the draft of the new curriculum we strive to develop conceptual understanding, strategic competence and adaptive reasoning. Our lessons focus on problem solving and the real world applications of mathematics.

The lessons focus on specific topics. However, we have linked them with key learning objectives that align to the curriculum specifications.

1st Class – An Introduction to Graph Theory
2nd Class – Cryptography
4th Class – Pick's Theorem and Geoboards
5th Class – Battleships Probability
6th Class – An Introduction to Python

We have built a website on HTML and CSS where our lesson plans, resources, computational tools and videos are available online. The name of our website is Geata Mata translating as "gateway to mathematics". We feel that this name is simple for students to understand and portrays mathematics as an open gateway for all to pass through. This website is available for teachers and students to use and can be accessed by clicking **here**.

It must be noted that our lessons are not rigidly fixed to the Irish Curriculum. Instead we endeavor to facilitate the development of key skills in the universal field of mathematics. Our vision is that the website can be implemented throughout the lesson where the teacher can use our PowerPoint's, exercises and computational tools to promote mathematics as an interesting, dynamic and rewarding subject.

2 Link to Literature

We design lessons based off the principles of Universal Design [1] and the TRU (Teaching for Robust Understanding) framework [3].

2.1 Universal Design

Universal design [1] focuses on dynamic and active lessons which are accessible to all learners. There are nine principles which underpin universal design. We provide an explanation of how our lessons target some of these specific areas.

1. Equitable Use
2. Flexibility in Use
3. Simple and Intuitive
4. Perceptible information
5. Tolerance for error
6. Low physical effort
7. Size and space for approach and use
8. A community of learners
9. Instructional Climate

Two of these areas we particularly focused on were Equitable Use and a Community of Learners.

Equitable Use; All students have access to the class content where a variety of explanatory materials are available to students. These include notes, slides, workbooks, and videos. There is no assumed prior knowledge and the teacher should make an effort to briefly revise topics that should have been addressed in previous years. According to Schoenfeld [2], "a classroom can only be considered powerful if it provides meaningful learning experiences for all students". Our lessons target students of all mathematical abilities and background. The lessons should have elements that challenge even the most talented students.

Community of Learners; Group work is incorporated into many of our lessons where students have an opportunity to discuss and build mathematical ideas with their peers and teacher. The teacher is envisioned to act as a facilitator of learning who can direct the lesson flow with questioning. The students should drive the learning in the lesson gaining a sense of agency and authority over their learning in the process in accordance with the TRU framework which we will discuss next.

2.2 TRU Framework

The TRU framework is detailed in the image below. Schoenfeld [3] states that there are five dimensions that contribute to powerful classrooms.

The Five Dimensions of Powerful Classrooms

The Content	Cognitive Demand	Equitable Access to Content	Agency, Ownership, and Identity	Formative Assessment
The extent to which classroom activity structures provide opportunities for students to become knowledgeable, flexible, and resourceful disciplinary thinkers. Discussions are focused and coherent, providing opportunities to learn disciplinary ideas, techniques, and perspectives, make connections, and develop productive disciplinary habits of mind.	*The extent to which students have opportunities to grapple with and make sense of important disciplinary ideas and their use. Students learn best when they are challenged in ways that provide room and support for growth, with task difficulty ranging from moderate to demanding. The level of challenge should be conducive to what has been called "productive struggle."*	*The extent to which classroom activity structures invite and support the active engagement of all of the students in the classroom with the core disciplinary content being addressed by the class. Classrooms in which a small number of students get most of the "air time" are not equitable, no matter how rich the content: all students need to be involved in meaningful ways.*	*The extent to which students are provided opportunities to "walk the walk and talk the talk" – to contribute to conversations about disciplinary ideas, to build on others' ideas and have others build on theirs – in ways that contribute to their development of agency (the willingness to engage), their ownership over the content, and the development of positive identities as thinkers and learners.*	*The extent to which classroom activities elicit student thinking and subsequent interactions respond to those ideas, building on productive beginnings and addressing emerging misunderstandings. Powerful instruction "meets students where they are" and gives them opportunities to deepen their understandings.*

Figure 1: TRU Framework [3]

In our efforts to abide by this framework we have created mathematical tasks that challenge students. However, the challenge is never beyond the *zone of proximal development* [4]. There is something for students of all mathematical backgrounds to engage with in meaningful ways. Students are encouraged to build on each others ideas, discuss mathematics and are invited up to the whiteboard in a number of lessons. All these factors contribute to students building an identity as a mathematician.

3 Computational Tools

3.1 Scratch

Scratch is a block based programming language. It is an extremely useful tool for creating animations, games and puzzles. Scratch also introduces children to concepts that underpin more complicated programming languages. Scratch implicitly addresses for loops, variables and functions in a user friendly fashion. We have designed games and learning support tools. In future lessons we hope to introduce students to coding in Scratch in 4th class.

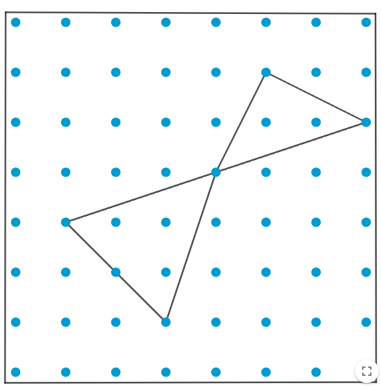
(a) Agent Game

(b) Taco Bandits Game

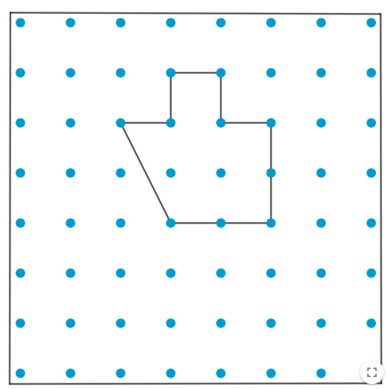
Figure 2: Two Cryptography Games

3.2 Geogebra

Geogebra is an interactive programme that can be used to display geometric objects. We designed a geoboard on geogebra to compliment our lesson on Pick's Theorem.



(a) Polygon



(b) Two Triangles

Figure 3: Geoboard Shapes

3.3 Python

In our lessons we introduce the students to Python. The function and importance of computer programming is discussed. We provide a tutorial on how to download Python and the Jupyter notebook. Students will learn how to perform simple arithmetic tasks on python. We introduce the concept of strings. Students will be encouraged to examine text and the properties of different strings. The print function will be introduced and by the end of the project students will compute letter frequency in a paragraph from a Harry Potter novel. We recommend that this lesson is conducted in a computer lab or similar environment. We have made several video tutorials for students to follow, and provide the teacher with an example of common students misconceptions. Some of these misconceptions include;

- Forgetting to put strings inside quotations

✗

```
I like pop music

  File "<ipython-input-52-b1c0554654f6>", line 1
    I like pop music
         ^
SyntaxError: invalid syntax
```

✓

```
"I like pop music"

'I like pop music'
```

- Forgetting to use brackets and parenthesis when working with functions such as print and len

✗

```
print(I am very hungry!)

  File "<ipython-input-49-aad058496f0b>", line 1
    print(I am very hungry!)
             ^
SyntaxError: invalid syntax
```

✗

```
print"I am very hungry!"

  File "<ipython-input-48-67ee37d40527>", line 1
    print"I am very hungry!"
                           ^
SyntaxError: invalid syntax
```

✓

```
print("I am very hungry!")

I am very hungry!
```

Our video tutorials, worksheets and python help sheet can be found on our website by clicking **here**.

4 Full Lesson Sample

4.1 5th Class Lesson - Battleships and Probability

4.1.1 Abstract

We introduce the game of Battleships through the lens of probability. This lesson should be really enjoyable for students as they are learning whilst playing a game. We begin by introducing the rules and providing the students with a 3 x 3 battleships grid. Students will play the game and record how many guesses it took to sink a ship. A frequency table will be completed. Students will record their results and display them graphically using bar charts. We will analyze the number of possible arrangements for a boat to be placed in the grid. We will consider which boxes are most likely to have a battleship in them and why this is the case. Students will then be encouraged to work out a mathematical strategy to play the game. A larger grid will then introduced and we can vary the boat size. Students will be encouraged to find the best places to place their battleships in these grids.

4.1.2 Sample Learning Objectives and Intentions

- Estimate the likelihood of occurrence of events
- Construct and use frequency charts and tables
- Count the number of possible arrangements when placing a battleship into a 3 x 3 grid.
- Determine which squares in this grid contain the largest number of possible outcomes.
- Collect experimental data for different games. (How many guesses it took to sink a ship)

4.1.3 Students' Prior Knowledge

- Use the vocabulary of impossible, unlikely, likely and certain
- Order events in terms of likelihood of occurrence
- Identify and record outcomes of simple random processes such as tossing a coin ten times.

4.1.4 Example Common Student Misconceptions

- The rules of the game may be a grey area for some students. Some students may try to put their ship diagonally across the grid.
- It is important to emphasize that winning the game isn't the ultimate objective and our results will only work if the children are honest and don't cheat.
- Playing the game without counting how many turns it took to win.
- Errors in reading data from a bar chart.

4.1.5 The Mathematics behind Battleships

4.1.6 Probability and Squares

Guessing the position of a battleship should be guided by probability. In order to develop a strategy we must consider the grid.

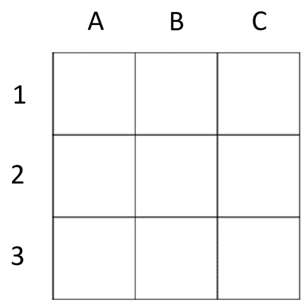
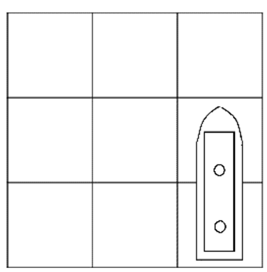
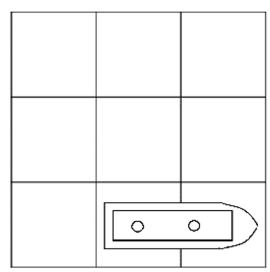


Figure 4: Playing Grid

As you can see in the figure above, there are nine squares in total for the 3 x 3 grid. Each battleship takes up two adjacent spaces on the grid. It is important to note that the orientation of the battleship is irrelevant. The diagram below shows two possible combinations of arranging the battleship on the grid. In total there are twelve unique ways of arranging a ship in this grid. Note that the ships cannot be arranged in a diagonal manor.



(a) Possible Combination



(b) Possible Combination

Figure 5: Two possible ways of arranging the battleship

We should also note which squares are occupied by a battleship. The figures above demonstrate that there are only two possible arrangements where the battleship lies in the C3 square. However, the middle B2 square can be occupied in four possible unique arrangements. This means that if a battleship was randomly placed on the grid there would be a 2/12 chance that a portion of it was in the C3 square and a 4/12 chance that a portion of it would be in the B2 square. This highlights how our guess should be guided by probability as some squares are more likely to be occupied by a battleship!

4.1.7 The Best Squares to Guess

As discussed in the previous section a randomly placed ship is more likely to occupy some squares. The diagram below highlights how many times each square is occupied for the twelve unique combinations of set-ups.

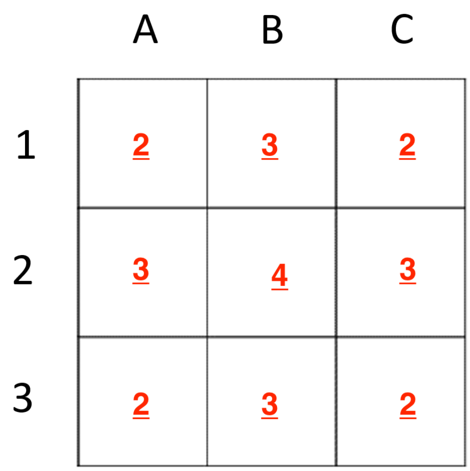


Figure 6: Square Occupation

Of course when you hit the ship for the first time your guesses should build on the information you have gained. For example, if on my first guess I choose to fire a missile at the A1 square and this missile hits a target, I know that I have at least a 50% chance of sinking the battleship in my next turn because it must be on A2 or B1.

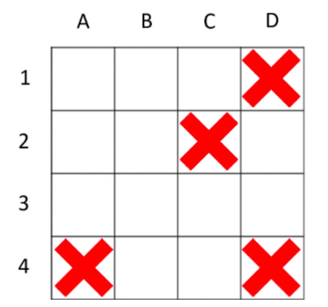
4.1.8 Gathering and Analyzing the Students' data

It is important to ask children to remember to count how many turns it takes them to sink the opponents battleship. We expect this to be roughly normally distributed with most games being completed after five or six guesses. Of course some games will take only two turns whilst some might last the full nine turns. The teacher should make sure the frequency table in the workbook is correctly filled in and work with the students in designing the bar chart.

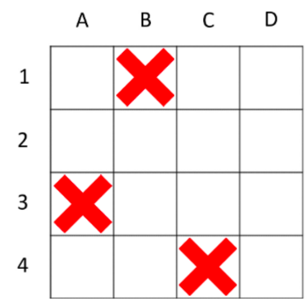
4.1.9 More Complex Games

It is also possible to introduce a 4 x 4 grid and keep the size of the battleship the same. However, we believe working out the associated probabilities with this larger grid is beyond the scope of the curriculum. Of course this is entirely up to the teacher and if one wishes to challenge their students or use this concept for an older class group we strongly encourage the design of more complex exercises.

We have devised some exercises suitable for 5th class children where a number of turns have already be completed, thus simplifying the game. In the following exercises the children are provided with a grid as shown below. The children are instructed to colour in the square that is now most likely to be occupied by a battleship. They must again list the number of possible times a square can be occupied by a battleship.



(a) Possible Game 1



(b) Possible Game 2

Figure 7: Two possible games

The exercise for the first figure has been completed below.

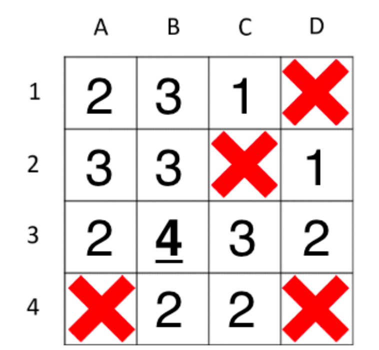


Figure 8: Solution to the exercise

5 Discussion & Future Work

We hope to begin sharing the website with teachers and schools via social media and connections. We would also like to receive feedback on our lessons from teachers that are using them in the classroom. Several methods of measuring the efficiency of the program can be explored. For example, data could be collected by creating an optional poll for teachers to provide feedback on the website.

Another possibility is to test these lessons out ourselves in schools. This could be done by going into a school to teach one of the lessons, and seeing how the students respond to it. The benefits of this method are that we can use the resources exactly as we had intended. We could also observe another teacher teaching their own class, which may be more accurate. Ideally, the teachers will read through the lesson plan before the class and then teach the lesson as based off our resources. This method is more realistic, as we will gain an insight into how a teacher who knows their own class utilizes the website. It also allows us to judge the effectiveness of the full website, including the lesson plans, whereas we may be more biased towards the effectiveness of our own resources if we teach the lessons ourselves. Using either method will allow us to gain valuable feedback from teachers who might want to use the website in their own classroom.

We would also like to add more lessons, as well as making 'sequel' lessons to those we have already created. These 'sequel' lessons may be designed for the same age/class, or they could be for an older class. For example, we could make another Cryptography lesson for 3rd Class, which could be taught without having done the previous lesson. We would particularly like to continue making Python tutorials. These are useful as it has been suggested that coding may be introduced to the new curriculum, in which case there will be a shortage of resources, especially Irish ones.

We would also like to extend the lessons up to secondary school. As the students would have a higher level of maths, this allows for a much broader range of lessons. Due to there being a lot of focus on the Junior and Leaving Cert in some years, we would focus on lessons for 1st and 4th years. There is likely to be a lot of demand for lessons for 4th year especially, as teachers are not allowed to begin the Leaving Certificate curriculum until 5th year.

6 Acknowledgments

We would like to thank our supervisor Dr Lennon O'Naraigh for all of his help with this project. We would also like to thank all of the staff in the UCD School of Mathematical Science office, as well as Dr Anthony Cronin for organising everything.

References

[1] NDA. (2014). Universal Design. Retrieved 1/07/2019. From http://universaldesign.ie/

[2] Schoenfeld, A. H. (2014). What makes for powerful classrooms, and how can we support teachers in creating them? *Educational Researcher*, 43(8), 404-412. DOI: 10.3102/0013189X1455

[3] Schoenfeld, A. H., The Teaching for Robust Understanding Project. (2016). An Introduction to the Teaching for Robust Understanding (TRU) Framework. Berkeley, CA: Graduate School of Education. Retrieved from http://map.mathshell.org/trumath.php

[4] Vygotsky, L. S., Cole, M. (1978). Mind in society: *The development of higher psychological processes*. London;Cambridge, Mass;: Harvard University Press.