EQUATIOBOTS

A game by Florence Derry

Overview & Gameplay

Equatiobots is a serious game designed to be played by secondary school students in maths classrooms, in groups of size 2-6. Each round, the players' goal is to work collaboratively to formulate a mathematical expression using random numbers (dice) and cards displaying operations (*Tool cards*, see fig. 2). Players physically place cards in between the dice to visually represent their expression on the game board (see fig. 5). They are scored (0-5 *Tinker tokens*, see fig. 4) by how closely each expression evaluates to a random target number, and must reach a total score of 13 to finish the game. A typical game should take around 20 to 40 minutes, depending on the number of rounds needed. On top of drawing Tool cards and rolling dice, players can also choose from a small selection of special powers (*Epiphany cards*, see fig. 3) each round, often allowing them a greater chance of success if used wisely.

The game is intended as a fun and engaging revision tool for students to practice the order of operations and problem solving skills in the classroom.

Learning Objectives

When conceptualising my serious game, there were two key factors that I had in mind.

Firstly, I wanted to create a game that addresses misconceptions held by secondary school maths students. For decades, it has been understood that misconceptions are a pervasive and arguably unavoidable aspect of learning mathematics (Confrey, 1990) that can have a profound impact on students' academic success. One particular area where misconceptions occur is in understanding the order of operations (Booth, *et. al.*, 2016), which I chose to focus on due to its wide applicability in other areas of mathematics - it's an essential skill.

My second goal was to translate some aspects of my experience studying maths at university that I've most enjoyed into a secondary school setting. In particular, problem solving and collaboration with peers, both of which I felt lend themselves quite naturally to the design of a serious game. The benefits of peer-to-peer learning in mathematics have been widely recorded (Hidayat, *et. al.*, 2023), meanwhile problem solving invites an aspect of creativity that is often overlooked in maths teaching.

As such, the main learning objectives for this serious game are:

(1) Players should **remember**, **understand** and be able to **apply** the **order of operations** when evaluating mathematical expressions.
(2) Players should **work collaboratively** in groups to **solve mathematical problems**.

During the game, players must demonstrate both learning objectives in order to make the most of the resources they have and score points. Specifically, players are explicitly instructed to work as a team, sharing their ideas and checking each other's work, and are reminded to ensure that they follow the order of operations when evaluating the expressions they have created. In doing so, students confirm their understanding – as defined in Bloom's Taxonomy (revised by Krathwohl (2002)) – by explaining their ideas to the group. Furthermore, students get immediate feedback on their ideas from peers, meaning misconceptions in order of operations can be identified and corrected in a comfortable environment, which Swan (2002) suggests as an evidenced method of improving understanding.

Furthermore, both learning objectives are mechanically supported. Rolling dice to generate random numbers ensures that players must apply their knowledge of order of operations to novel examples – again, in line with the definition given in Bloom's Taxonomy (Krathwohl, 2002). Since the game is intended as a revision tool, it does not explicitly list the order of operations, meaning it is up to players to remember them. This also makes the game more accessible to a variety of classrooms, as, while the principles are universal, different schools teach the order of operations differently, so establishing one specific definition has the potential to cause confusion (Zazkis & Rouleau, 2018). The randomness of both dice and cards also allows for a wide variety of problem solving approaches during play, as no two rounds are the same. The Epiphany cards incentivise playing in larger groups, as each new player brings a potential different solution each round through the use of their specific card.

Design & Development

My initial inspiration for *Equatiobots* was the 'numbers rounds' from the game show *Countdown* (Jammot & Stellman, 1982–present), in which players have 30 seconds to arithmetically combine 6 random numbers to reach a three digit target number. Knowing that this game is already used in maths classrooms to practice arithmetic problem solving, I considered it a good basis for adaptation for my serious game concept.

The first step of adapting the game to the tabletop was to use dice for the random numbers. I chose to use a full set of seven polyhedral dice typically used in TTRPGs, since they have a range of expected values, and are generally readily available. Early personal playtesting of this central mechanic confirmed that the standard set of dice was suitable, with a low chance of encountering a problem with no solutions.

Next, I wanted to more intentionally incorporate using the order of operations in the gameplay, leading me to add the mechanics of randomly drawn Tool cards and fixed dice positions. This significantly limited player options when problem solving, forcing more creative use of operations and requiring more consideration of their order, however it also made the game more challenging as a result, and therefore less accessible to the target audience. To mitigate this, I added the Epiphany cards as special 'one-time' abilities, allowing for more player agency. With these, I was inspired by the 'draw 3, choose 1' mechanic from *King of Tokyo* (Garfield, 2011), further emphasising player choice. This was motivated by the theory of *flow* (Csikszentmihalyi, 1990), wherein difficulty should be balanced with player agency and expected success in order to maximise the engagement of the audience. To further address this concept and avoid players being demotivated by failure, I decided to base scoring on a 'window of success': effort is always mechanically rewarded, but more Tinker tokens are awarded for reaching closer to the target.

With the mechanics of gameplay in place, I decided to add an element of game narrative, hoping to further motivate school-age players by contextualising the abstract concepts of arithmetic and order of operations (Fiore, et. al., 2007), as well as to help the game feel more original and fun, rather than merely a classroom exercise. Specifically, I chose a steampunk aesthetic – with the players acting as 'tinkerers' – drawing from the concept of problem solving and my own interests. In this narrative framework, the dice are contextualised as robot parts, and the abstract 'points' scored are used to fix the players' airship, leading to the narrative goal of escaping the island on which they are stranded. The story also helps to rationalise mechanics such as player collaboration and problem solving.

Finally, the visuals of the game followed from both the narrative and demographic contexts, inspired by the look of engineering blueprints and the gridlines typically found in maths exercise books. I created all the artwork for the game, using a pixel art style as this is what I'm most experienced with. In particular, the game board (*Blueprint*, see fig. 1) is relatively simple, communicating wordlessly, and coloured using only two blue shades, all of which was intended to make it as visually accessible as possible and manage the cognitive load of players (Sweller, 1988).

Prototyping and Playtesting

Due to printing limitations, the prototype for *Equatiobots* had very small cards, which playtesters found difficult and frustrating to use at times, however this is something I plan to account for and remedy with any future manufactured prototypes. The artwork was widely praised, with one playtester commenting, “I love the visual design...the colour is super chill”, and another “liked the concept of the airship”. The table below shows the changes made to the game in response to playtester feedback.

Playtester feedback/suggestion	**Action**
It’s somewhat difficult to separate Tool and Epiphany cards into separate piles.	Make Epiphany cards larger than tool cards, increase the size of cards overall in future prototypes. Ensure that each card type has their respective symbol on the back to help with identification.
Some Epiphany cards (specifically ‘discard/draw’) are less useful and less fun to use than others (‘switch/reroll dice’).	Change the distribution of Epiphany cards to include more ‘switch/reroll’ cards and relatively fewer ‘discard/draw’ cards.
Some Tool cards occur too frequently and cannot be used effectively, ending up ‘stuck’ in hand over successive rounds.	Change the distribution of Tool cards by removing two of six ‘÷’ cards and four of twelve ‘(‘ cards.
Non-integers can cause confusion when scoring.	Added a note to the rulebook that players should round to the nearest integer if scoring is ambiguous.
Some students may find the game more motivating if there is a competitive element.	Added advice for teachers to the rulebook, suggesting that groups of students may compete to finish the game in the fewest number of rounds.

Otherwise, the feedback from playtesters mostly concerned the visuals and interpretation of the rulebook, leading to minor compositional and grammatical edits. The most significant change to the game in response to playtesting was the addition of the ‘Tips for Teachers’ page of the rulebook, condensing rules clarifications, examples and optional gameplay changes in order to help teachers use the game as a teaching tool, while keeping the rest of the rules relatively simple and straightforward.

Unfortunately, the biggest limitation of this initial period of playtesting was the inability to have students within the target audience play the game and give feedback, as this would allow me more insight into how to tailor the game to that demographic.

What's Next?

Overall, I have enjoyed the process of designing and creating a serious game, and I'm very satisfied with the current state of my game. I plan to have a refined version of the prototype manufactured, hoping to demonstrate *Equatiobots* at the UK Games Expo 2026. I would also like to have students in the target audience try out the game, and potentially develop it further based on their feedback.

When it comes to putting *Equatiobots* on the market, while I currently don't plan on working with an official publisher, I have considered making a 'print & play' version of the game, allowing it to be more financially accessible to maths teachers. I have also thought about creating and distributing the game on *Tabletop Simulator*, as I have previously used it to play other board games from independent creators.

Appendices/Figures

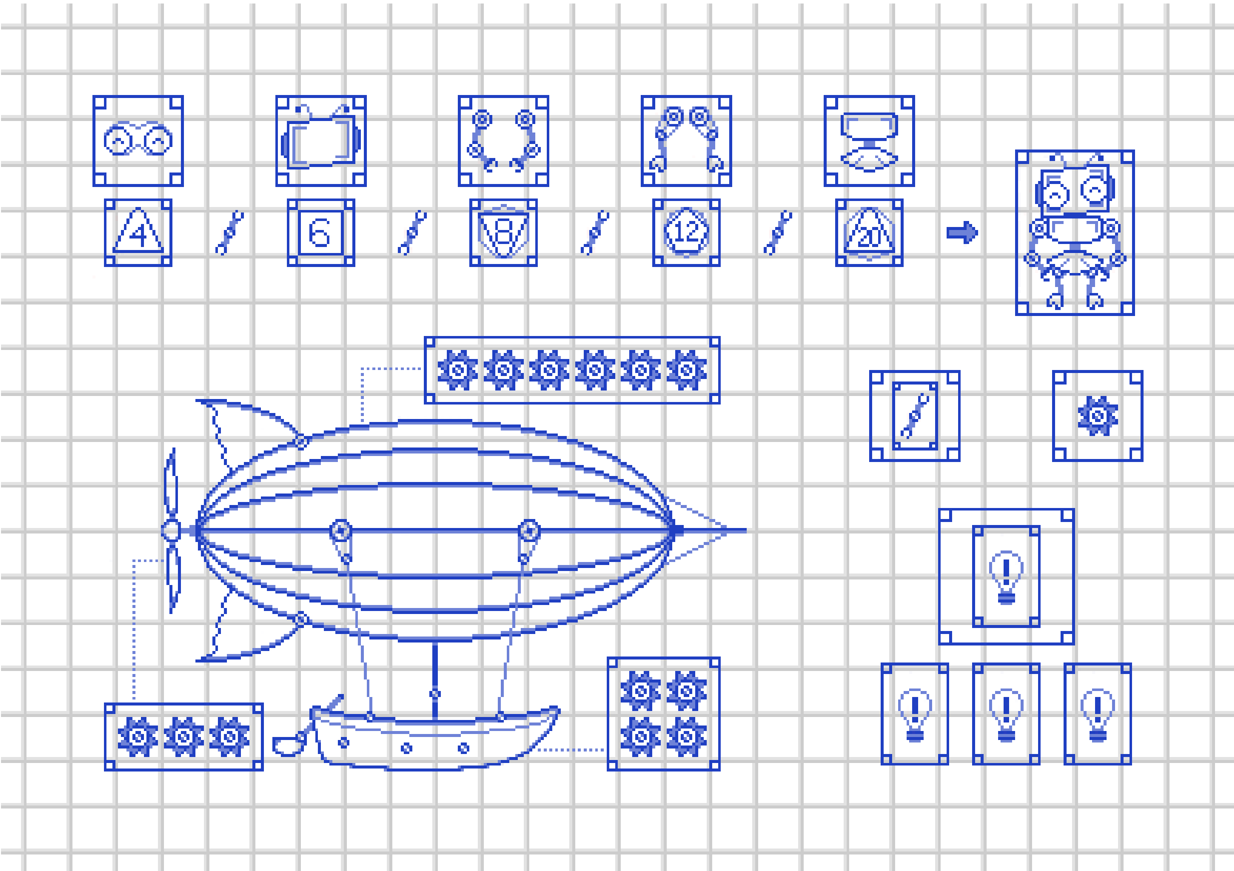

Fig. 1, *Blueprint*. The game board, with positions for dice, cards and tokens.

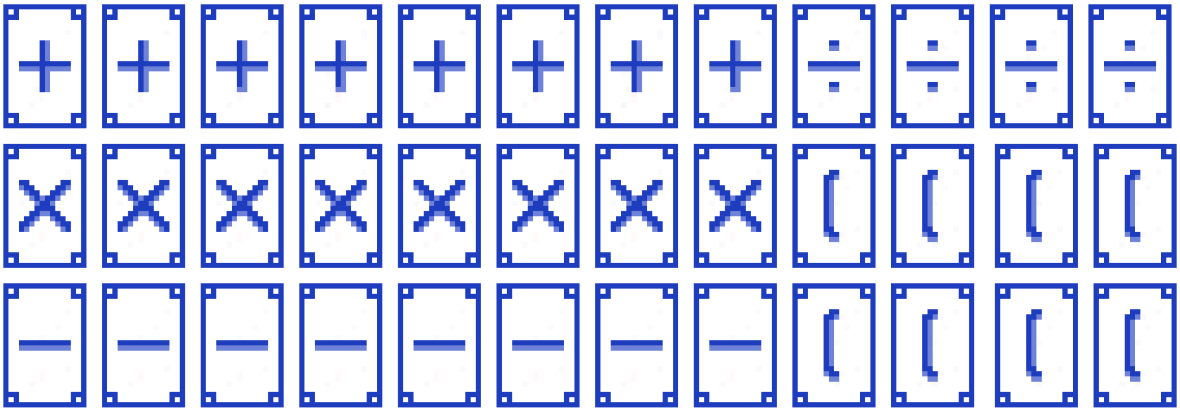

Fig. 2, *Tool Cards*. These cards visually represent arithmetic operations and brackets, and are placed in between the dice to form an expression. The quantity of each card shown equals their quantity in the deck.

Fig. 3, *Epiphany Cards*. These cards allow players to perform specific actions detailed on each card. The quantity of each card shown equals their quantity in the deck.
The blank card is not used.

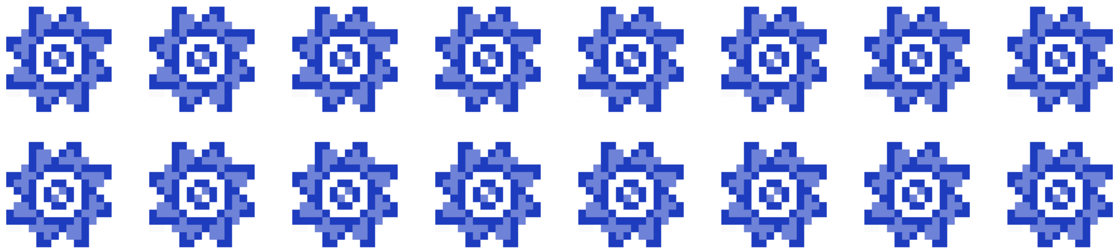

Fig. 4, *Tinker tokens*. These tokens are used for scoring the players' success, with (at least) 13 having to be obtained in order to complete the game.

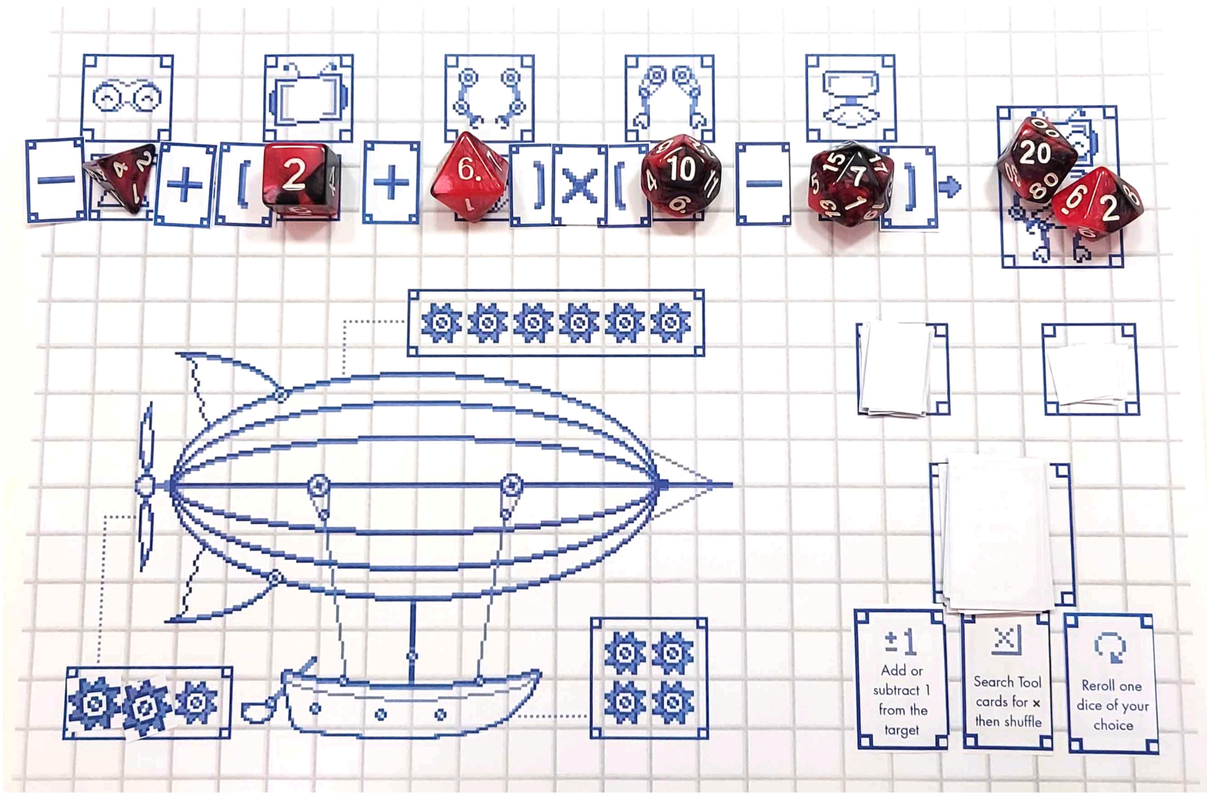

Fig. 5, *Equatiobots prototype*. A picture of the printed prototype taken during gameplay, showing cards and dice placed on the blueprint.

References

Booth, J.L., McGinn, K.M., Barbieri, C., Young, L.K. (2016). 'Misconceptions and Learning Algebra,' in Stewart, S. (ed.) *And the Rest is Just Algebra*. Springer, Cham, pp. 63-78.

Booth, L.R. (1982). 'Getting the Answer Wrong'. *Mathematics in School*. Vol.11, No.2, pp.4-6.

Confrey, J. (1990). 'Chapter 1: A Review of the Research on Student Conceptions in Mathematics, Science, and Programming'. *Review of Research in Education*. Vol.16, No.1, pp.3-56.

Csikszentmihalyi, M. (1990). 'Flow: The psychology of optimal experience'. New York: Harper & Row. Vol. 1990, p. 1.

Fiore, S., Metcalf, D., & McDaniel, R. (2007). 'Theoretical foundations of experiential learning'. *The handbook of experiential learning*. Pfeiffer, pp. 33-58.

Garfield, R. (2011). *King of Tokyo* [Board game]. IELLO.

Hidayat, R., Nasir, N., Fadzli, S.A.M., Rusli, N.S., Kamaruzzaman, N.N., Sheng, V.Y.Z., Mohammad, N.H.H. and Shukeri, A.S. (2023). 'Peer tutoring learning strategies in mathematics subjects: Systematic literature review'. *European Journal of Educational Research*, 12(3), pp.1407-1423.

Jammot, A. & Stellman, M. (1982–present). *Countdown* [TV Series]. Lifted Entertainment.

Krathwohl, D. R. (2002). 'A revision of Bloom's taxonomy: An overview'. *Theory into practice*, 41(4), pp. 212-218.

Swan, M. (2002). 'Dealing with misconceptions in mathematics'. *Issues in mathematics teaching*. Routledge, pp. 147-165.

Sweller, J. (1988). 'Cognitive load during problem solving: Effects on learning'. *Cognitive science*, 12(2), pp. 257-285.

Zazkis, R., & Rouleau, A. (2018). 'Order of operations: On convention and met-before acronyms'. *Educational Studies in Mathematics*, 97(2), pp. 143-162.