

Teacher Instructions for Power arRangers

Team Fallout

Technical Background

The electric grid refers to the network of power providers and consumers which are interconnected by transmission and distribution lines. Commercial electricity is made at power plants by huge generators; from there, the current passes through transformers. Transformers decrease the current and increase the voltage, which allows the electrical potential to travel long distances with little power lost. The voltage is lowered at a substation, from which the electrical charge is passed to distribution lines: the smaller lines which go into neighborhoods. From the distribution lines the voltage is again reduced to the level locally needed for private or commercial use [1].

The American Society of Civil Engineering (ASCE) gave the American electrical grid a “D+”, falling between “Requires Attention” and “At Risk” according to their grading scale [2]. Much of the grid was built more than 50 years ago, during a time when “electricity was primarily a luxury.... Most people didn’t require computers to do their jobs every day. They didn’t need the Internet access. iPhones didn’t need to be charged,” says Lynch, vice president of Power Line Systems, which provides consulting services for the design of power lines. Over the last 50 years, the investment in the grid has not kept up with increasing demand or the base maintenance of the system, leading to the low grade assigned by the ASCE [3]. Now, the grid’s state of disrepair is resulting in \$197 billion in unnecessary costs from 2012 to 2020, and the damage continues to grow [4]. Each unplanned power outage costs an affected business \$1000 on average and disrupts services for consumers. Meanwhile, the grid’s general dysfunction raises the cost of electricity for everyone through ‘congestion charges’. We need to spread awareness of this and effect solutions soon, because this problem will only worsen in the coming decade with the growth of the US population and energy consumption [2].

Engaging Interest:

Why it matters to the students:

We will capture the students' attention through challenging gameplay, while sparking the curiosity to work in STEM fields. Many people, especially those disposed towards STEM, will be engaged simply by the challenge of the puzzle. Students will be interested in the introductory lecture because it provides historical context and tips for the game. It is easy to find a solution, but it is hard to find the best one. That makes this game attractive and challenging even for adults, as well as kids.

In addition, we will explain to the students why the proper functioning of the power grid is of immense importance to everyone, how all of their household devices require electricity to work. This will motivate them during the activity and fix the awareness that they gain from this module in their memory.

Why now:

Limited resources limit solutions; this problem is incredibly visible in the decaying power grid infrastructure of the United States, and known solutions exist. The resources allocated are inadequate, as much of the grid is over 40 years old but was made to stand only 20 years. It is clear that the current budget is not enough to maintain the system at a high enough level to meet demand. The continued decay of the grid will collapse the infrastructure, causing billions of dollars of damages. The ASCE has recommended where to upgrade and repair the grid to prevent this collapse and save billions of dollars over the next 15 years. The plan only needs start-up funding. This existing solution is more efficient than the current solution in both the service it provides and the cost it is provided at. The billions that would be saved over the next 15 years could be reinvested in searching for solutions to other Grand Challenges or to search for further solutions in energy production and distribution.

There is a great deal that needs to be done to ensure the continuing prosperity of humanity, but not enough resources to do all of it at current efficiencies. The resources

allocated to the upkeep are far too small to meet its needs; this continued behavior will collapse the infrastructure, causing billions of dollars in damages. This leaves only a few options: bear the cost of a failing infrastructure, increase the budget for its upkeep, or find new ways to provide and maintain the infrastructure at lower costs. The United States cannot afford a failure of the power grid, and allocating additional resources naturally raises questions: "Where will the money come from?" and "Where will budgets be cut?". If we wish to enjoy the benefits of ubiquitous power, our future will require better methods than continued spending to support demand.

We are already seeing the consequences of a vital infrastructure being neglected as billions of dollars of productivity are lost each year to small power outages. This problem will only be amplified as our demand for power grows. If we are to flourish in a world reliant on technology, we must encourage new generations to start thinking about the problem of our decaying infrastructure.

Teacher Instructions

Preparation: Before “Game-Day”

1. Buy a pegboard and cut it into 2'x2' boards. You might check your local Sears, Home Depot or equivalent for a pay-per-use table saw.
2. For each pair of boards, choose a map design from Appendix B and paint the board according to the map.
3. Buy a package of pre-cut, $\frac{1}{4}$ inch wide dowels (about 1 $\frac{1}{8}$ inches long).
4. Buy a package of small rubber bands of at least two colors. Designate one color as the 'power plant color' and the other(s) as the 'population color(s)'. For each board that you will use, wrap 5 dowel pieces with various numbers of the 'power plant color'. Do the same with 16 dowel pieces with various numbers of the 'population color(s)'.
5. Buy three balls of yarn of different colors; designate one color of yarn for use in Stage 0, a second for use in Stage 1, and a third for use in Stage 2.

Stage 0: Before Game Play

Note: This simulates the expansion of the power grid and cuts down on game time. The set-up described gives the students a variety of options in how to approach Stage 1.

1. Set up a 'Legend' for the dowels in one corner of each board with a line of 1-black-band power plant dowels representing 5x power generated, 2-band power plant dowels representing 10x power generated, 3-band power plant dowels representing 15x power generated; a line of 1-color-band population dowels representing 1x population, 2-band population dowels representing 2x population, 3-band population dowels representing 3x population. Have a label above each line of dowels delineating what each dowel represents. We did this by writing on scotch tape attached to pegboard, so it could be altered easily in the future.
2. Place the Stage 0 power plant and population dowels on each board as directed by the Round 0 map in Appendix B.

3. Connect those dowels with Stage 0-color yarn as directed by the Round 0 map in Appendix B.
4. Place Stage 1 power plant and population dowels on each board as directed by the Round 1 map in Appendix B.
5. Choose about $\frac{1}{3}$ of the Stage 0 lines and mark them as 'aging' by drawing a line in the pegboard under them with a contrasting-colored dry-erase marker.

Stage 1

1. Place the boards on separate tables, or as far apart as possible so the "teams" can work independently.
2. Have 1-4 students sit around each board. Distribute handouts to students. Give them all a short overview of the historical background behind the activity, explain the basic rules of the game, and then give them a minute to attempt the "Before Stage 1" question on the Design Journal page in the handout. This should take about 15 minutes in total, but note that the students should only be given about a minute to attempt the first Design Journal question.
3. Give the students some of the Stage 1 color yarn. Give the students 15 minutes to do Stage 1 building. Try to provide supervision for all the groups to solve points of confusion and to ensure that all players are following the rules.
4. After they finish Stage 1, give them 5 minutes to tally up the total costs and arrive at a final value. Then give them 5 minutes to work through the first two "Between Stages 1 and 2" questions on the Design Journal page in the handout.
5. While they are performing step 3, go through their boards and add new units of population to existing cities, as well as new cities to the map, as directed by the map being used for that round. Additionally, flip a coin for each 'aging' line that was not chosen to be fixed by students and, if the coin lands heads up, draw a perpendicular line next to that stretch of yarn with a black dry erase marker to indicate that that line is broken.
6. Once Step 4 is completed, have the students answer the last "Between Stages 1 and 2" question on the Design Journal page in the handout for about a minute.

Stage 2

1. Give the students some of the Stage 2 color yarn. Give the students 10 minutes to do Stage 2 building. Try to provide supervision for all the groups to solve points of confusion and to ensure that all players are following the rules.
2. After they finish Stage 2, give them 5 minutes to tally up all the costs and arrive at a final value. Then have them spend 5 minutes working through the “After Stage 2” questions on the Design Journal page in the handout.

Cleanup

1. Untie the pieces of yarn from the dowels and throw them in the trash (unless they are large enough that they might be useful in future run-throughs of this activity).
2. Pull the dowels out of the boards and put them in a Ziploc bag for storage.
3. Use an eraser or paper towel to clean up the dry erase marker marks on the boards.

Materials and Budget:

This list of supplies creates 8 game boards, serving a class size of 32.

Material	Price per Unit	Number	Sub Total	Suggested Source
4'x8' White Peg Board	\$17.25	1	\$17.25	http://tinyurl.com/z3g745x
1/4" Dowel Pins	\$15.99	1	\$15.99	http://tinyurl.com/hwkety4
Colored Bands	\$4.89	1	\$4.89	http://tinyurl.com/zxp5gsp
Black Bands	\$5.19	1	\$5.19	http://tinyurl.com/glqhtsc
With Common Supplies Price:			\$43.32	
Paint*	\$8.88	1	\$8.88	http://tinyurl.com/h9bdwle
Paint Brushes*	\$4.99	1	\$4.99	http://tinyurl.com/hlp3gv4
Dry Erase Markers*	\$10.88	1	\$10.88	http://tinyurl.com/j52thfu
Yarn*	\$2.88	3	\$8.64	http://tinyurl.com/hd5ntwu
Scissors*	\$6.32	1	\$6.32	http://tinyurl.com/qfplcuo
Rulers*	\$7.08	1	\$7.08	http://tinyurl.com/h6jeca7
Without Common Supplies Total Price:			\$90.11	

*Indicates materials which are commonly available in the classroom and will likely not have to be purchased

Notes:

- The White Peg Board will need to be cut into 2'x2' sections. Make the cuts between the peg holes.
- The Peg Board can often be found for a discount price if it's damaged (often only decreasing the usable number of game boards from 8 to 7)
- Ensure that the 3 units of yarn are bought in different colors to help children distinguish wires laid between different rounds.

References

[1] Alliant Energy. "How Electricity Gets to Your House". Web. Available: <http://www.alliantenergykids.com/EnergyBasics/AllAboutElectricity/000416>. [Accessed: 10 Jan 2016]

[2] American Society of Civil Engineers. (2013). "2013 Report Card for America's Infrastructure". Web. Available: <http://www.infrastructurereportcard.org/a/#p/energy/overview>. [Accessed: 10 Jan 2016]

[3] Halsey III, Ashley. (2012, August). "Aging power grid on overload as U.S. demands more electricity". Web. Available: https://www.washingtonpost.com/local/trafficandcommuting/aging-power-grid-on-overload-as-us-demands-more-electricity/2012/08/01/gJQAB5LDQX_story.html. [Accessed: 10 Jan. 2016]

[4] Economic Development Research Group. (2012). "Electricity Report." Web. Available: http://www.asce.org/electricity_report/. [Accessed: 10 Jan. 2016]

Appendix A. Handout

Design Journal

Before Stage 1

After looking at the map, approximate how many inches of yarn you think it will take to connect all of the “new” cities to power plants. What is your reasoning?

Between Stages 1 and 2

How close was your yarn approximation? Why do you think you were that close?

Did you pay for maintenance on your lines? Why or why not?

After receiving Stage 2 cities, approximate how many inches total it will take to connect the new cities in addition to your current yarn.

After Stage 2

How close was your yarn approximation? Why do you think you were that close?

Did you do anything differently in Stage 1 that made Stage 2 easier?

Did paying or not paying maintenance in Stage 1 work out for you? Would you have done anything differently given Stage 2?

If you played this game again, what strategy would you use?

Game Play

Stage 1

- The dowels with colored bands represent city populations that need power.
- Power plants, the dowels with black bands, can be placed on land between the cities to provide power for them.
- Upgrade power plants and tie yarn between power plants and cities so that all the cities are appropriately powered.
- Some of your lines have aged and may break if not fixed. They are marked, and you can choose to pay \$100 per maintained line to fix them and avoid them possibly breaking in the future.

Stage 2

- Some existing cities have grown in population and new cities have appeared. You need to upgrade and expand your power grid to power new demand.
- Some of your old, marked power lines may have broken if you didn't pay for their maintenance in Stage 1. These will be marked as broken and can no longer transmit power. You will need to pay for removing that line and for laying a line there again as normal if you want to transmit power there.

Game Rules

- **At some point during the game, either while laying your lines or afterwards, number all of your power lines.**
- Cable lengths should be measured from dowel tip to dowel tip and recorded in the Yarn Length Table next to the line's corresponding number.
- A power plant can only power as much total population in the cities it's connected to as it has power output.
- A power plant cannot be connected to another power plant.
- Power lines can only branch from power plants and cities.
- Removing cable costs \$100 for a stretch of cable that is 3 inches long or less and \$200 for a stretch of cable that is longer than 3 inches. Record this in the penalties table.
- Any time that a cable crosses water (not just touching one edge of it), a \$50 penalty is added. Record this in the penalties table.

Stage 1 Data Tables

Building or Upgrading Power Plants

Units of Power Capacity	Cost	Number of Power Plants Used	Cost to Upgrade from Previous Level	Number of Upgrades Used
5	\$500		-----	-----
10	\$800		\$350	
15	\$1150		\$400	
Total	-----	-----	-----	

Cable # | Cable Length

Row Subtotal

1		2		3		4		5			
6		7		8		9		10			
11		12		13		14		15			
16		17		18		19		20			
21		22		23		24		25			
Total Yarn Cost (\$10/in.)								Total Yarn Length (in.)			

Penalties

Penalty Type	# of Penalty	Cost per Penalty	Total Cost
Water Crossing		\$50	
Cable Removal (≤3 in. >3 in.)		\$100 \$200	
Cable Maintenance		\$100	

Add up Power Plants, Power Cables, and Penalties for Total Stage 1 Cost	
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Stage 2 Data Tables

Building or Upgrading Power Plants

Units of Power Capacity	Cost	Number of Power Plants Used	Cost to Upgrade from Previous Level	Number of Upgrades Used
5	\$500		-----	-----
10	\$800		\$350	
15	\$1150		\$400	
Total	-----	-----	-----	

Cable # | Cable Length

Row Subtotal

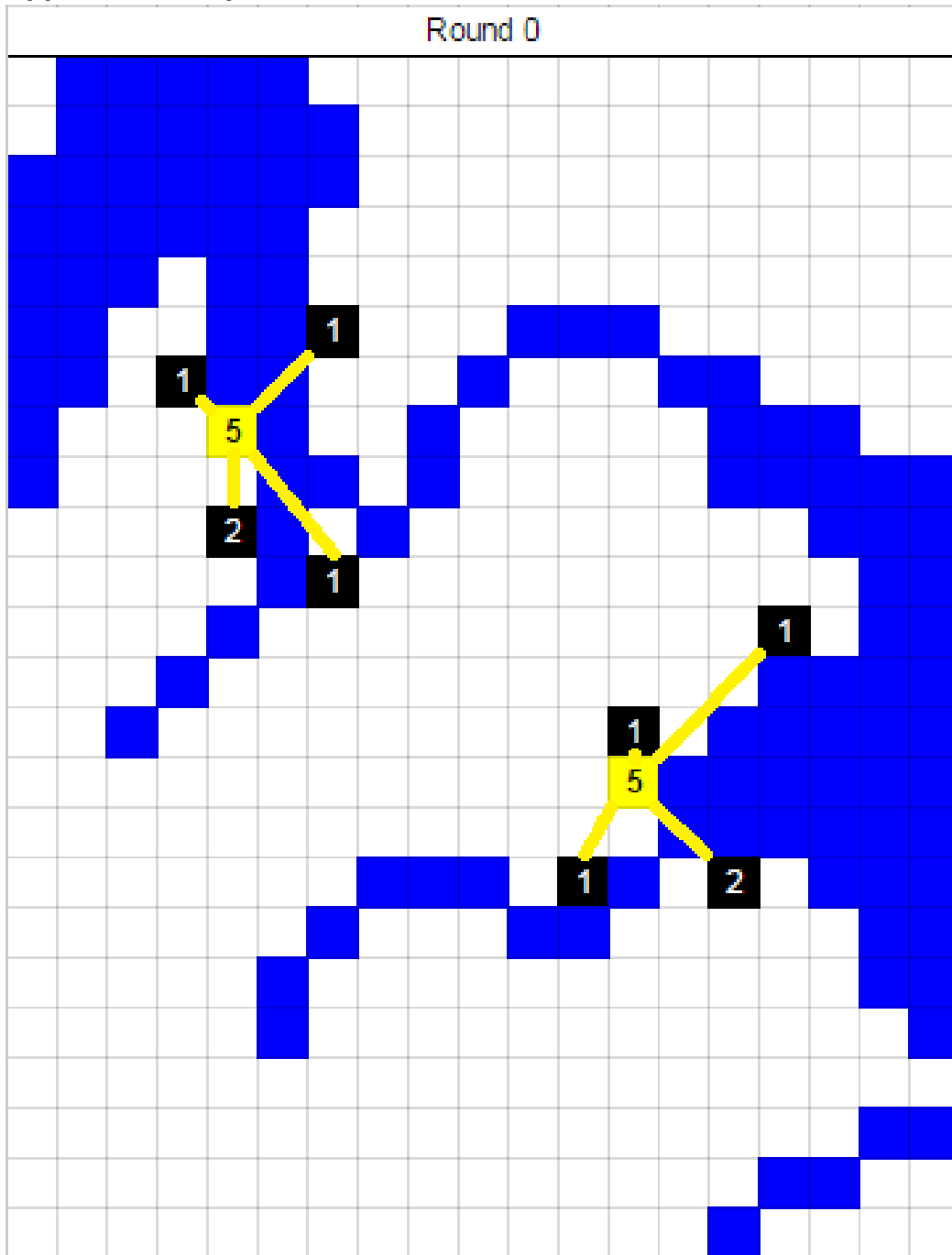
1		2		3		4		5			
6		7		8		9		10			
11		12		13		14		15			
16		17		18		19		20			
21		22		23		24		25			
Total Yarn Cost (\$10/in.)								Total Yarn Length (in.)			

Penalties

Penalty Type	# of Penalty	Cost per Penalty	Total Cost
Water Crossing		\$50	
Cable Removal (≤3 in. >3 in.)		\$100 \$200	

Add up Power Plants, Power Cables, and Penalties for Total Stage 2 Cost	
Add up Total Costs for Stages 1 and 2	

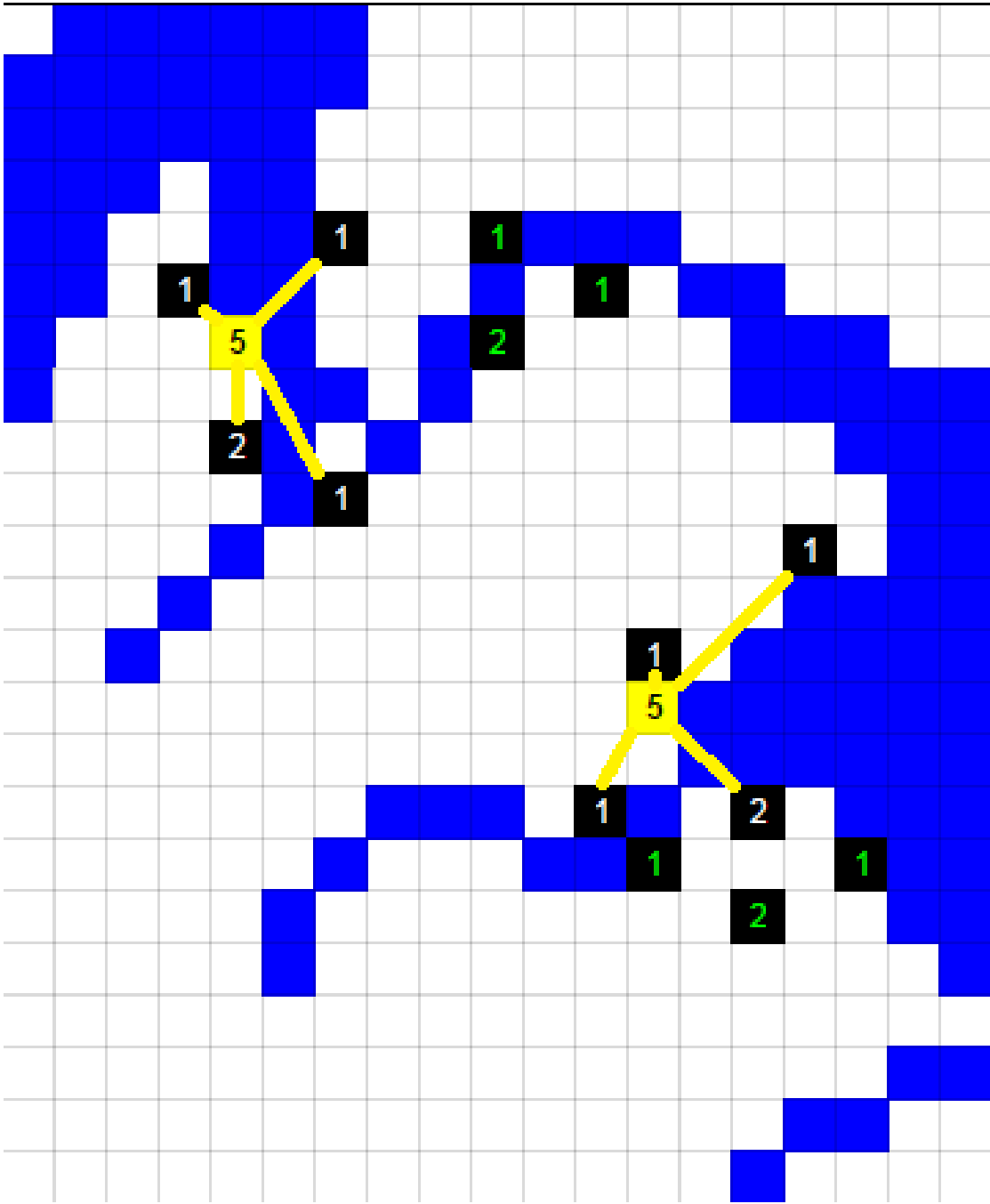
Appendix B. Maps



KEY

- Yellow Square= Power Generator
 - The number inside represents power production level
- Black Square= Population center
 - The number inside represents population/power consumption level
- Yellow Line= Power Cable

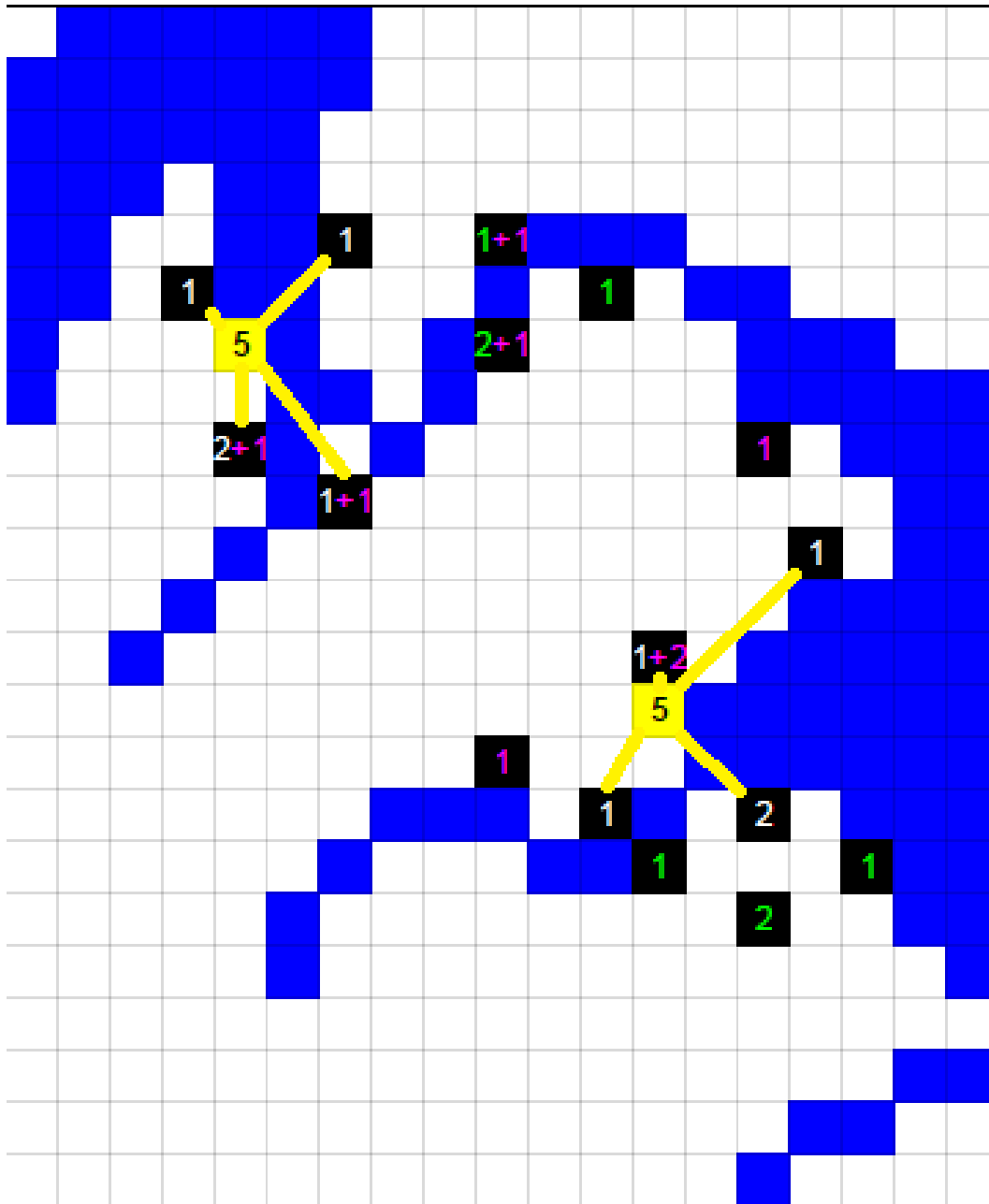
Round 1



KEY

- See Round 0 Key
- Black Square with Green number= new city added after Round 0

Round 2



KEY

- See Round 1 Key
- Black square with a red number= a new city added after Round 1
- A red number in an existing population center= population increase equal to the red number

Appendix C. Board Setup

