Computational Thinking Concepts in GAM 224

Concept 1: Representation of Rules

The textbook for the course[1] introduces three types of rules for games: constituative, operational, and implicit. Operational rules are the guidelines players require in order to play, such as the rules printed on the box of a board game. Constituative rules are the underlying logical and mathematical structures in the game. Implicit rules are the "unwritten" rules of the game, such as rules about decorum. Important here are the first two types of rules: constituative and operational. Two games are considered to be the same if there is a 1-1 relationship between the constituative rules of the two games, so that if you can find a winning strategy in one game you can use the mapping to find a winning strategy in the other game. At the same time, the operational rules for two structurally identical games can vary significantly. While the operational rules are what make a game enjoyable to play, the constituative rules are the ones that more experienced players are using when they find winning strategies.

This concept is an example of the design principle, one that allows students to see the relationship between abstraction of rules, the modeling of game behavior, and the underlying structure of a game that results from the representation of different rules.

Learning Goal: Students will be able to abstract the operational rules of a simple board game to find the underlying constituative rules for the game and use the constituative rules to comment on strategies that may exist for the game.

Case 1: Tic-Tac-Toe and 3-to-15

The following is an in-class activity:

The (operational) rules of Tic-Tac-Toe are as follows:
1. Play occurs on a 3 x 3 grid of 9 empty squares
2. Two players alternate marking empty squares, the first player marking Xs and the second player marking Os
3. If one player places three of the same marks in a row (horizontally, vertically, or diagonally), that player wins
4. If all the spaces are filled and there is no winner, the game ends in a draw

Play Tic-Tac-Toe for 5 minutes to learn/remember how the game works.

The (operational) rules of 3-to-15 are as follows:
1. Two players alternate turns

[1] *Rules of Play: Game Design Fundamentals*, Katie Salen and Eric Zimmerman, The MIT Press, 2004.

2. On your turn, pick a number from 1 to 9. You may not pick a number that has already been picked by either player.
3. The first person to obtain a set of exactly 3 numbers that sum to 15 wins the game
4. If all numbers between 1 and 9 have been chosen and no player has a subset that sums to 15, the game ends in a draw

Play 3-to-15 for 10 minutes to learn/remember how the game works.

Discussion Questions:
1. What strategies exist for Tic-Tac-Toe? Include both strategies for winning and for preventing the other player from winning.
2. What strategies exist for 3-to-15? Include both strategies for winning and for preventing the other player from winning.
3. Are the two games the same? Why or why not?
4. The two games have the same constituative rules. This can be seen by using the following translation between the two games, where placing an X or an O on a square amounts to picking the number in the corresponding square:

2	9	4
7	5	3
6	1	8

5. Translate a strategy for Tic-Tac-Toe into a strategy for 3-to-15 using the above table. For example, describe a blocking strategy for 3-to-15 derived from a blocking strategy for Tic-Tac-Toe.
6. Which game is easier to play using its operational rules? Why do you think that is the case?

Case 2: Chutes and Ladders

The following is an in-class activity:

Chutes and Ladders is a children's board game. Its rules are as follows:
1. Everyone spins the spinner (which has the numbers 1 – 6) on it. The player with the highest number goes first. Play proceeds to the left.
2. On your turn, spin the spinner and move your pawn, square by square, the number shown on the spinner. For example, if you spin a 5 on your first turn, move to square #5 on the board. Once you move your pawn, your turn is over.
3. Two or more pawns may be on the same space at the same time.
4. Any time a pawn ends its move on a picture square at the bottom of a ladder, that pawn must climb up to the picture square at the top of the ladder.
5. Any time a pawn ends its move on a picture square at the top of a chute, that pawn must slide down the chute to the picture square at the bottom of the chute.
6. If your pawn ends its turn on any of the following spaces, your turn is over:
    a. A square with no picture
    b. A square with no picture and just an arrow
    c. A square that a ladder or chute just passes through

   d. A picture square at the top of the ladder
   e. A picture square at the bottom of a chute
7. The first player to reach square #100 wins the game. You can get there two ways:
   a. Land there by an exact count. If your spin would take you past square #100, don't move. Try again on your next turn.
   b. Climb there by ending your move on ladder square #80

The board for the version of *Chutes and Ladders* considered in this activity can be found here: http://photos.artificialtruth.com/d/24806-1/chutesladdersboard.gif The goal of this activity is to find the set of constituative rules of *Chutes and Ladders*.

Discussion Questions:

1. How can you represent the spinner? Ideally what does a spinner produces for you? (Answer: A random number between 1 and 6)
2. How can you represent the player's movement on the board without using a board? (One answer: Each player has a running total, a number between 0 and 100, that represents their position on the board)
3. How will the "chutes" be represented? Explicitly list all of the constituative rules that must be included for the "chutes" in the game. (Answer: Reaching some values automatically causes the player's total to be lowered. Those values (and the corresponding result) are: 16 → 6, 47 → 26, 49 → 11, 56 → 53, 62 → 19, 64 → 60, 87 → 24, 93 → 73, 95 → 75, 98 → 78)
4. How will the "ladders" be represented? Explicitly list all of the constitutative rules that must be included for the "ladders" in the game. (Answer: Reaching some values automatically causes the player's total to be lowered. Those values (and the corresponding result) are: 1 → 38, 4 → 14, 9 → 31, 21 → 42, 28 → 84, 36 → 44, 51 → 67, 71 → 91, 80 → 100)
5. How do you handle the winning condition using this model? (Answer: You can only reach 100 either by reaching 80 or by getting to 94 or beyond and receiving a random number that takes you to exactly 100).
6. Does the purely constituative version of *Chutes and Ladders* have the same feel as the original game? Why or why not?
7. Are there any strategies that the constituative rules make clear to you? Why or why not? (Answer: The game is highly dependent on chance and there are no obvious strategies. This is fairly common for board games designed for children. Discuss why that is.)

Assessment: Consider the board game *Candyland*. The operational rules for *Candyland* can be found here: http://www.hasbro.com/common/instruct/Candyland.PDF A picture of the board can be found here: http://www.lscheffer.com/CandyLand.jpg

Construct a set of constituative rules for *Candyland* by:

1. **Constructing a table that represents the positions on the board for each of the color blocks and picture cards. The table should**

include a representation for the two shortcuts (gumdrop pass and rainbow trail).

2. **Describing a way to randomly produce each of the card combinations from the deck.**
3. **Describing how each of the 3 penalty spaces (gooey gumdrops, lost in the lollypop woods, and stuck in the molasses swamp) will be handled in your rules.**
4. **Describing the winning condition for the game.**

After you have constructed the constituative rules, describe any strategies that the rules make clear. If there are no strategies that your constituative rules illuminate, explain why that is. Is it a property of your representation? Or is it a property of the game?

Concept 2: Understanding Cybernetic Systems

GAM 224 places a strong emphasis on games as systems, and one of the ways of seeing a game is as a cybernetic system. A cybernetic system that is set up so that movement in the system in a certain direction is encouraged is called a positive feedback loop. A positive feedback loop has the effective of creating exponential growth or decline in some aspect of the system. A system in which movement in a certain direction is halted is called a negative feedback loop, and its effect is to stabilize a system or maintain equilibrium.

This concept is an example of both coordination and evaluation. It requires students to model and understand the internal state of a game system, the mechanisms detecting the game state, and the mechanisms altering the game state. In order to create a game that is balanced, students must understand how the alteration of the game state affects the player's perception of the fairness and competitiveness of the game.

Learning goal: Students will be able to describe what a negative or positive feedback loop is, how such a feedback loop can be incorporated into an existing game, and how that feedback loop impacts the experience of both winning and losing players in the game.

Case 1: Classifying feedback loops

The following is an in-class activity:

Recall that a cybernetic system is one in which the behavior of the system is controlled by a negative feedback loop, a positive feedback loop, or in some cases, several of each. A negative feedback loop acts to move the state of the system in the direction of its previous state. A positive feedback loop acts to move the state of the system in the direction it is currently moving.

Listed below are a series of game rules found in common board games. For this activity, you must:

1. Determine the classification for the rule: positive feedback loop, negative feedback loop, or neither.
2. If you decide that rule includes a positive feedback loop, you must indicate what direction the game state is moving in and how the rule aids the movement of the state of the system.
3. If you decide that a rule is a negative feedback loop, you must indicate what state the rule is trying to preserve and how the rule keeps the game in that state.
4. If you decide that the rule is neither a positive nor negative feedback loop, you must indicate why.
5. In the case that the rule is a negative or positive feedback loop, describe the impact that the rule has on a player who is winning and the impact that the rule has on a player who is losing. How would each type of player perceive the rule?

The game rules are:

1. You must reach the final/winning square (square 100) in *Chutes and Ladders* with an exact roll. For example, if you are on square 96 and you roll a 6, you do not advance but instead lose your turn.
2. In *Checkers*, if a piece reaches the far end of the board, then it becomes a "king"**.** (A "king" is usually signified by stacking two checkers one on top of the other). A "king" is allowed to move and jump diagonally backward and forward, unlike ordinary pieces which may only move and jump diagonally forward.
3. In *Candyland*, penalty spaces on the board cause players to remain stuck in a certain position until they draw a specific card that frees them from the space.
4. Players landing on properties owned by another player in *Monopoly* must pay rent. A player who owns an entire color group of properties may charge double the rent for any unimproved property in that color group.

Case 2: Describing feedback loops

The following can either be an in-class activity or part of an assignment:

Recall that a cybernetic system is one in which the behavior of the system is controlled by a negative feedback loop, a positive feedback loop, or in some cases, several of each. A negative feedback loop acts to move the state of the system in the direction of its previous state. A positive feedback loop acts to move the state of the system in the direction it is currently moving.

Find one example of a positive feedback loop and one example of a negative feedback loop in a computer game you have played. For each of the positive and negative feedback loop examples you must describe:

1. The game in which each example appears. Provide a sufficient introduction to the game so that someone who has not played it would be able to understand its basic

premise. You do not have to choose one game for both types of feedback loops, but each game you choose must be described.

2. The situation or rule that represents a positive feedback loop, the direction that the game state is moving when the positive feedback loop begins, and how the positive feedback loop enhances that game state.
3. The situation or rule that represents a negative feedback loop, the state the situation or rule is trying to preserve, and how the negative feedback loop causes the game state to be stabilized.
4. Your opinion about whether the positive feedback loop enhances the game play. Be specific about how the positive feedback loop modifies game play, paying special attention to its impact on both the winning and losing players.
5. Your opinion about whether the negative feedback loop enhances the game play. Be specific about how the negative feedback loop modifies game play, playing special attention to its impact on both the winning and losing players.

Assessment: Consider an existing board, card, or computer game. Modify the game to include a positive or negative feedback loop not already present in the game. In doing so, describe:

1. **What game you have chosen in sufficient detail so that someone unfamiliar with the game understands the premise and basic game play.**
2. **Precisely where in the game (under what circumstances and when) you are introducing the negative or positive feedback loop**
3. **How the negative or positive feedback loop works, and what game state it is either enhancing (in the case of a positive feedback loop) or stabilizing (in the case of a negative feedback loop)**
4. **How your change to the game makes it more fun. What balance issues is the change to the game addressing? How will the change to the game affect winning and losing players? Do you anticipate any potential problems that your change could introduce?**