Co-enactment of Spatial and Logical Reasoning in Game Play: The Case of Santorini

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Background

The call to back-to-the-basics has highlighted mastering the fundamentals of mathematics with an emphasis on arithmetic. Viewing mathematics as more than an emphasis on numbers, we consider *reasoning* as basic to mathematical thinking and learning. Games, specifically commercial abstract strategy games, in mathematics class have the potential to **broaden the purpose of school mathematics** to invite students to experience joy in mathematical thinking and learning (NCTM, 2020). Even though games develop meaningful understanding of mathematical ideas, they are devalued in compulsory schooling and remain under researched (McFeetors & Palfy, 2018; Reid, 2002b).

This study focused on spatial and logical reasoning as elementary students played Santorini. The study's aim was to examine how students' interactions with Santorini occasions enactment of spatial and logical reasoning.

Theoretical Foundation

Theory of Experience
Dewey (1938/1997) proposed that students learn by (inter)acting in and on the world around them, including physical and intellectual engagement, so that an event is meaningful and leads to growth. 'Doing' is transformed to 'learning' as students reflect on their experiences and ascribe meaning to them.

Spatial Reasoning (SR)
Ability to visualize and mentally manipulate shapes, both real and imaginary, we will as navigate and relate to the physical world around us (Cohen & Hegarty, 2012), recognize relationships (Carroll, 1993) and track shapes along a path (Newcombe & Frick, 2010). Figure 1a represents the complexity of spatial reasoning skills and the complementary nature of these mental and physical actions (Davis et al., 2015).

Logical Reasoning (LR)
Ability to engage in systematic pattern of behavior (Reid, 2002a) or in developing thinking or argument (Brodie, 2010). Logical structures can be deductive/inductive (Polya, 1954), analogy and metaphor (English, 1997) and transformational (Simon, 1996). Figure 1b represents the logical reasoning wheel adapted from McFeetors & Palfy (2017).

Accumulation of experience is key for every learner. Games provide students a platform to enact *SR* and *LR* to gain sufficient mathematical reasoning *experiences*.

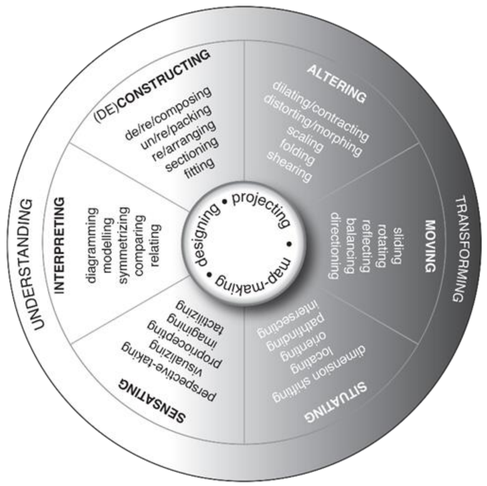

Figure 1a. Spatial Reasoning Wheel

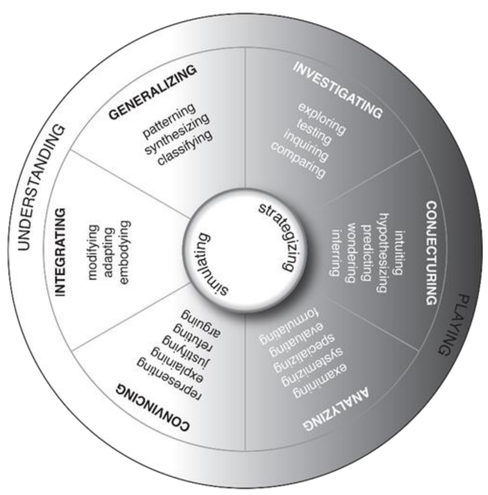

Figure 1b. Logical Reasoning Wheel

Methods

Design-based research methodology (Cobb et al., 2003; McKenney & Reeves, 2012): games used as interventions
Project length: 2 years
Participants: Grades 4-6 (Edmonton + Calgary schools)
Preliminary findings from: A 60-minute session/week for 5 weeks of Santorini gameplay with 44 students
Data collection: Reflection sheets, videos, photos and researchers' field notes
Data analysis: Use of SR and LR wheels (Figure 1a & b) to code student actions and utterances

Results

Students engaged in co-enactment of spatial and logical reasoning (SLR) to develop effective strategies. We share three student examples to demonstrate the co-enactment:

1. Locating & Exploring (Grade 5)
Exploring the game and understanding where to *locate* pawns. Figure 2a shows the intentional board set-up. B1 and G1 *located* in corners, and B2 and G2 *located* close by. Students *explored* the game rules and strategies in relation to *location* of their pawns. Figure 2b shows Grey *locating* G1 and G2 close to corners where as Blue 'sticking to the opponent' and placing their B1 and B2 adjacent to Grey. SLR was co-enacted in initial *exploration* of Santorini where *locating* workers was critical to learning the game rules.

Figure 2a

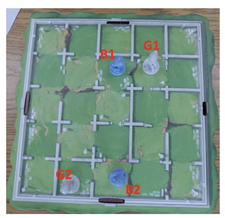

Figure 2b

"One of our characters is close to our opponents, and [the other] *in our own corner"* (Blue)

"One worker has to be close to the opponents' workers, the other should be in our own private area" (Grey)

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Results

2. Pathfinding & Analyzing (Grade 6)
Pathfinding involves understanding and navigating through space to reach a destination. In Santorini, *pathfinding* was seen as students mentally and gesturally interacted with the board, *analyzing* the levels, directions and (un)available spots to move their pawns. Figure 3a shows Blue *analyzing* potential moves of the opponent. G1 only had one viable path (red arrow). Blue moved B1 down a spot and constructed a dome in the adjacent space (Figure 3b). Blue *analyzed* possible *pathways* for both players and successfully trapped G1 in the top right corner.

Figure 3a

Figure 3b

3. Sectioning & Modifying (Grade 4)
Sectioning divided the game board into different areas for strategic play. *Modification* was seen as students altered their gameplay in response to the opponents moves. In Figure 4a, Blue noticed G2 entering the section on the left. Blue sealed off the section using additional domes (Figure 4b). Grey *modified* the gameplay by using the two-tower strategy which involves constructing two adjacent towers to step up to the third level for a win (Figure 4c). Both players *modified* their strategies in different sections of the board, with G2 successfully reaching the third level (Figure 4d)

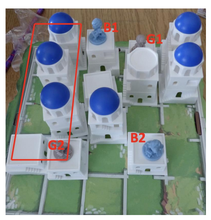

Figure 4a

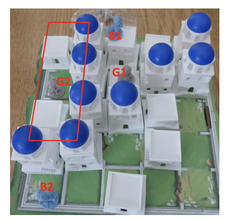

Figure 4b

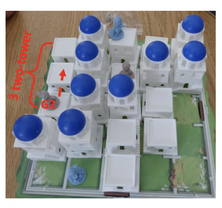

Figure 4c

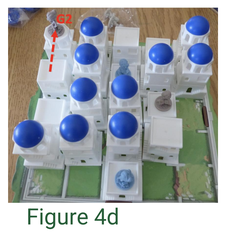

Figure 4d

"The corners [are] more useful, so you can create a mini zone"

"Have your own little section"

"There is a way I can win"