Board Games as Play-full Pedagogical Pivots for STEM Teaching and Learning

Marc Higgins
& Janelle McFeetors
University of Alberta

Abstract:
Drawing inspiration from Ellsworth's (2005) work on thinking with pedagogically non-prescriptive objects and the pedagogies they permit and prohibit, we turn our attention to similar educational "texts" increasingly used in STEM (i.e., science, technology, engineering, mathematics) education—board games. We tinker with board games as they refuse and resist the ways that STEM education often privileges cognitive destinations rather than relational learning journeys that enfold the whole learning self, the content, as well as the materiality of learning. We ask, how might games simultaneous act as locations of, and as, pedagogy that inflect experiences of student learning? To answer this question, we explore the pedagogical intents expressed by game designers themselves by their design diaries, blogs and interviews while thinking with Ellsworth's concept of *pedagogical pivot*. In exploring game designers' statements, we map out some of the potentialities that this pedagogical medium might offer STEM teaching and learning.

Keywords: STEM education; pedagogy; pedagogical pivots; games; play

Des jeux de société comme pivots pédagogiques pleins-de-jeux en l'enseignement et l'apprentissage de STIM

Résumé :
S'inspirant des travaux d'Ellsworth (2005) sur la réflexion relative à des objets pédagogiques non normatifs et aux pédagogies qu'ils permettent et interdisent, notre attention est portée sur des "textes" éducatifs similaires de plus en plus utilisés dans l'enseignement des STIM: les jeux de société. Nous expérimentons le fait que les jeux de société ne se prêtent pas aux manières selon lesquelles l'enseignement-apprentissage des STIM privilégie les cheminements cognitifs plutôt que des parcours d'apprentissage relationnels qui englobent toute acquisition, le contenu ainsi que la matérialité de l'apprentissage. Nous nous demandons comment les jeux pourraient simultanément fonctionner comme endroits d'apprentissage, et même comme une pédagogie, qui modifient les expériences d'apprentissage des étudiants? Afin de répondre à cette question, nous explorons les intentions pédagogiques des concepteurs de jeux en lisant leurs journaux de conception, blogs et entretiens, tout en établissant un rapport avec le concept des pivots pédagogiques de Ellsworth. En explorant les déclarations des concepteurs de jeux, nous avons élaboré certaines des potentialités que cet outil pédagogique pourrait offrir à l'enseignement et à l'apprentissage de STIM.

Mots clés : éducation de STIM; pédagogie; pivots pédagogiques; jeux de société; enjouement

> We could be playing for education stakes—to improve skills, to widen our access to knowledge. But, as crucial as it is to our survival in the real world to play for such goals, we must first acknowledge our community of and our intention of playing well together. We are playing to learn. We are playing to learn because that particular challenge intrigues us. We begin playing and end playing with the knowledge that we are already worthy and good and wise. What we win is the opportunity to play with that knowledge, and, in so doing, to play well, and, in so playing, to discover that there is yet more for us to play with.
>
> (de Koven, 2013, p. 128)

As teacher educators and educational researchers studying K-12 schooling, we are beginning to see board games used more frequently within school settings. This mirrors a larger societal shift whereby board games are becoming a more popular medium through which to engage in processes and practices of play (e.g., Fournier, 2019). Board games can and are used to meaningfully develop spatial reasoning and logic, explore and mathematically model scientific concepts, and engage in questions of user interface and design (e.g., Byrne, 2017; McFeetors & Palfy, 2017, 2018; Odendaal & Zavala, 2018). By design, board games are pedagogically non-prescriptive educational texts: they do not guarantee that players will reach a desired, singular curricular destination. This characteristic, as de Koven (2013) signals above, could be read as a playful differentiation of learning that responds to the gifts and the communities of learning that learners already have. Yet, in formal educational contexts, the pedagogical potential of games is often perceived as limited. Such perception cannot be separated from educational preoccupations with (al)ready-made and transferable knowledges that do not come to challenge teachers' constructions of self and taken-for-granted knowledge structures (e.g., Britzman, 1986). It is for this reason that Ellsworth (2005) provocatively states,

> Perhaps one of the most potent challenges that educators could mount against knowledge as a thing already made and the interests it supports and perpetuates would be this: to make schools places where the force of children's passages into and within the spaces between what we think we know about the world and its relationalities is augmented and assembled in ways that inflect the social body's ways of knowing with children's ways of knowing (p. 143).

Game authors and scholars underscore that games have long been both constructed and understood as a medium which is at odds with teaching and learning in linear and formalized ways, and that might rather, after Ellsworth (2005), follow children's playful ways of knowing (e.g., Begy, 2017; de Koven, 2013; Faidutti, 2013a, 2013b). In this article, we look to trouble the notion that board games and formal education do not align. We seek to recover the pedagogical potential of these non-prescriptive educational texts at a time in which we desperately need children to think (and dream!) in creative, critical and collective ways (e.g., Bazzul, Wallace, & Higgins, 2018). Extending earlier scholarship about board games in STEM (i.e., science, technology, engineering, mathematics) education (e.g., Byrne, 2017; McFeetors & Palfy, 2017, 2018), we situate this work within a growing body of relational pedagogies that come to consider the ways in which learning selves and the

learning itself are differential experiences that are always in the making rather than prescribed destinations that can be fully anticipated and articulated (e.g., Dewey, 1934; Ellsworth, 2005; Lenz Taguchi, 2010). This is in line with critiques of STEM education as far too often overcoded through the privileging of singular cognitive destinations rather than relational learning journeys that enfold (at least) the whole learning self, the content, the social context in which coming-to-know occurs, as well as the materiality of learning (e.g., Bazzul & Kayumova, 2016; Chesky & Wolfmeyer, 2015; deFreitas, 2016; deFreitas & Sinclair, 2013).[1]

We are called by curiosity. What and how might we learn from new types of educational experiences that board games present? In following this line of inquiry, we turn to and "tinker with" (Higgins, Wallace, & Bazzul, 2018) board games as texts that refuse and resist such aforementioned acts of pedagogical signification. However, we take seriously the notion that "at the moment critical conversations within the humanities and social sciences . . . that emphasize and rely on critique and methods of negation over and above methods of construction or invention have become counterproductive" (Ellsworth, 2005, pp. 127-128). Rather than the subtractive movement of critique, we engage herein with the multiplicative possibilities that might occur through the cross-product of STEM education and games as playful pedagogy. Particularly, our affirmative critique centers around how we can *play to learn* and how considering board games as media also invites simultaneous exploration of the significance of how we might *learn to play* (de Koven, 2013; see also Faidutti, 2013b). In response to this special issue's guiding inquiry, we imagine STEM education as potentially being a place of loving kindness through *playfulness*.

We frame this exploration in two interwoven parts. First, we begin the larger project of mapping out the ways in which a board game may act as and be a *pedagogical pivot* (Ellsworth, 2005) that fosters what Dewey (1934) refers to as *an* experience of learning. Enfolding both pedagogies and their locations, pedagogical pivots are *places of learning* (e.g., spaces, events, objects, etc.) that act "as the vehicles through which we come to know differently" (Ellsworth, 2005,

[1] Herein, we take seriously and employ Ellsworth's (2005) citational politics, which privileges secondary sources over primary:

> Secondary sources are always open to the suspicion that they may not provide valid interpretations of the primary source. Often, they are regarded as being merely rhetorical, specifically if they use words and ideas from the originating thinkers to argue a point or persuade an audience as opposed to referring to an "original" contribution to a field of study (p. 11).

The consequence of such suspicion, as Ellsworth (2005) states, is that particular (and often unproductive) hierarchies are reproduced and reified between primary and secondary sources. Above and beyond the frequent re-centring of a Western and masculine canon of knowledge, Ellsworth notes that there are particular consequences for education. First, such faithfulness to an origin relegates education to the position of secondary field to disciplines of the humanities, as well as the natural and social sciences. Second, the field of education itself internally re-inscribes such a hierarchy, namely, between curriculum and pedagogy.

Through privileging secondary sources throughout, we attempt to employ them "in ways that render problematic—better yet, render useless and uninteresting—the whole idea of a primary source as something that requires the subordination of other sources as secondary" (Ellsworth, 2005, p. 12). This is particularly significant as our project within this paper is to (a) attune and attend to the differential ways in which pedagogy is excessive of curriculum; and (b) take seriously the work of a diverse citational web whose theory-practice is already proximal to the questions arising from learning to play and playing to learn in STEM education without rendering them subservient to more established conceptions of teaching, learning and knowing.

p. 37) by putting the inside and outside into relation (e.g., self and other, known and not-yet-known). Specifically, in reading game designers' and scholars' work *through* Ellsworth's (2005) notion of pedagogical pivot, we illuminate three pedagogical pivots that playing to learn and learning through play might activate:

1) the aesthetic and affective experience of learning (e.g., the visual art of the game, the tactile feel, the accessibility of the game design);
2) the ways in which interaction reconfigures relationality (e.g., between players, between players and text, between players and the world beyond the game) which includes relations to STEM concepts both implicitly (e.g., probability, spatial-logical reasoning) and explicitly (e.g., thematic of game); and
3) the porous boundaries between seriousness and playfulness as well as openness and close(d)ness (e.g., through the rule set, possibilities for competition and collaboration).

Second, taking cues from art educators who ask what we can learn from artists about pedagogy (e.g., O'Donoghue, 2011), we explore what we can learn from game designers of STEM-related games regarding the ways this *play-full*[2] medium of board games might support learning within STEM classrooms. Specifically, we explore Gordon Hamilton's thoughts on his game *Santorini*, reflections made as both a designer and mathematician. We establish *Santorini* as a potential site for mathematics learning through Hamilton's claim that "the number one reason we teach mathematics [is to] get kids into problem solving, and games are such a natural celebration of problem solving. That's why there is such a strong connection" (Hamilton in Eddy, 2017, 26:30-26:42). While connections between *Santorini* and particular mathematical concepts and skills are available, we intentionally resist identifying predetermined curricular destinations to highlight the importance of thinking mathematically (Mason, Burton, & Stacey, 2010), which became readily apparent to us in our own playfulness with *Santorini* as avid board game players.

In short, *Santorini* is an accessible combinatorial abstract strategy game[3] that is played on a five-by-five grid with stacking three-dimensional building pieces. The goal is to move one's pawn to the top of a stack of three building pieces—but it is not as easy as it sounds! On every turn, a player first moves one of their two builder pawns into a neighbouring space (orthogonally or diagonally) so long as that space would not require the builder to leap upward more than one level (although they can jump down as many levels as they would like), nor move into another builder pawn's space. Secondly, using the builder pawn they just moved, they construct a level of a building in a

[2] As a nod to Derrida (1976), the term *play-full* is a (near-)homonym to *playful* that is meant to defer and differ its meaning through the *play of resignification*. Within this article, we use it to accentuate the ways in which games are not only fun (i.e., playful), but are also rife with (i.e., full of) potentialities in terms of the relations that are differentially activated, re(con)figured and yet-to-come (i.e., play).

[3] In the larger family of board games, abstract games are those in which their theme, if they have one at all, is not central to the play (e.g., chess, checkers). Within this sub-family, there are *combinatorial* abstract games. Combinatorial games can further be qualified as not including hidden information (e.g., hidden units as in *Stratego*), luck or randomness (e.g., rolling dice as in *Backgammon*), or simultaneous play (i.e., planning and playing turns at the same time as in *Rock-Paper-Scissors*). While many combinatorial abstracts permit more than two players, not all do. However, at the player count of two, these games are highly strategic events, alive with the back-and-forth posing of logic puzzles.

neighbouring space by placing it onto the board. However, if the level would be the fourth, a dome is placed instead, removing that space from play. Once someone has moved a builder onto a space of height three, the game is over. However, there are also rule-bending *god* cards that change what a player can and cannot do, as well as alternate winning conditions, which make every play of the game unique.

Our starting place to explore *Santorini* as a pedagogical pivot toward *an* experience of learning mathematics is with Hamilton's design diaries—publicly available statements that describe the process of conceptualizing, developing, testing and publishing a board game—forming a data set within which we explore the anticipation of educational interactions and bring to life the three aforementioned qualities of experiencing games' *play-full pivots* (e.g., porous boundaries). Ellsworth (2005) argues that while indeterminate curricular texts often exceed their intended purpose, there is nonetheless much to be learned from those who create them.

Our intent is to stretch ourselves beyond just-new-thought, animating the possibility of not-yet-thought with illuminating examples for mathematics play. We recognize that mathematics as a discipline is one of four areas included in STEM, and we simultaneously join a timely conversation in examining the role and emphasis of mathematics within STEM (Chesky & Wolfmeyer, 2015; Wallace, 2019). While the specific board game chosen, in keeping with this particular special issue, emphasizes mathematics learning, we anticipate our identification of pivots can be similarly applied to games related to science, technology and engineering education. Indeed, we suggest the framework we develop below could be taken up in all areas of STEM education to generatively engage with the experiences of students with and through games.

Thinking with Ellsworth: Games as Pedagogical Pivots

> Knowledge, once it is defined, taught and used as a "thing made," is dead. It has been forced to give up that which "really exists": its nature when it is a thing in the making, continuously evolving through our understanding of the world and our own bodies' experience of and participation in that world. with. (Ellsworth, 2005, p. 1)

In making sense of games as pedagogical medium, we "think with" (Jackson & Mazzei, 2012, 2017) Elizabeth Ellsworth's (2005) *Places of Learning*. We turn to Ellsworth, as her work on pedagogically non-prescriptive texts, such as media, art and architecture, opens up a space to consider the ways in which learning is more than the transmission of knowledge as a *thing made* and to consider the types of learning experiences that occur when we take seriously that knowledge is *always in-the-making*. Knowledge as always in-the-making, as games scholar and designer de Koven (2013) suggests, is an inescapable quality of games themselves: they are "social fictions, performances, like works of art, which exist so long as they are continuously created" (p. xxiii). Further, in line with some of the qualities of games already mentioned, Ellsworth (2005) theorizes the ways in which these places of learning are more than texts to be hermeneutically interpreted. Rather, they are agentic in the construction of material-semiotic experiences which cannot be (fully) known

in advance: "Like all systems and structures of address, pedagogy is unable to contain or control where and when its address arrives or how it is taken up" (Ellsworth, 2005, pp. 54-55).

Jackson and Mazzei's (2012, 2017) research orientation of *thinking with theory* can be succinctly described as "reading-the-data-while-thinking-the-theory" or "as a moment of plugging in, of entering the assemblage, of making new connectives" (2012, p. 4). It is a research stance that actively works against decontextualization of knowledge-making by encouraging the explicit, transparent and intentional engagement with the theories with which we think. Further, this stance challenges the *grounding* of excessive knowledge-in-the-making, such as that offered through the multi-faceted (e.g., affective, algorithmic, socio-cultural, material) play of games, as well as processes that (re)produce what is already known and knowable through the frameworks we already hold (which then hold us). Importantly, Jackson and Mazzei (2012, 2017) encourage us to move beyond thinking with scholars who reflect back to us what and how we already know. Instead, they suggest turning to those who offer a "productive provocation: theorists who open up thought rather than foreclose it" (2012, p. 5).

In this spirit of productive relational play, we engage with Ellsworth (2005) to "help us think something that we cannot think otherwise" (Jackson & Mazzei, 2012, p. 15). Given our focus on how board games act as multi-faceted texts, we draw on Ellsworth's work of thinking with pedagogically pluralistic and non-prescriptive objects, and the pedagogies they permit and prohibit. Specifically, we are inspired by her discussion about how these places of learning act as a *hinge* or *pivot* towards something beyond what we (can) already know:

> For pedagogy to put us in relation to that outside—for pedagogy to put us in relation to thinking—it must create places in which to think without already knowing what to think. It must create a relationship to the outside, to others, to the world, to history, and to the already thought in a way that keeps the future of what we make of that relation and what we might think there open and undecided. (Ellsworth, 2005, p. 54)

Ellsworth's (2005) concept of *pedagogical pivot* calls attention to the ways that teaching and learning objects inflect the learning-self-in-the-making by placing the self in relation with something that is simultaneously both self and beyond the self: "self, others, and the world" (p. 57). She argues that this is significant in processes of teaching and learning as "thought is able to confront us from the only place where it can confront us: from outside the concepts we already have, outside the subjectivities we already are, outside the material reality we already know" (Ellsworth, 2005, p. 55).

As board games are more-than-objects that loosely frame multiple learning potentialities through their spatially represented game states and sets of rules (e.g., Begy, 2013; Wehrle, 2016), we believe that they fit the description of such pedagogically productive yet non-prescriptive texts. More directly, we see games as being and enacting the kinds of pedagogical pivots that Ellsworth (2005) describes in her work regarding the pluralistic potentiality exhibited by art, media and architecture. Games designer and scholar de Koven (2013) describes a game as

> something that provides us with a common goal, the achievement of which has no bearing on anything that is outside the game . . . [such that it is] not intended to replace reality but to

> suspend consequences . . . [while, simultaneously, games] *are* works of art, they do reflect reality (p. xxiii; emphasis in original).

Here, reading de Koven (2013), thinking with Ellsworth (2005) and exploring Hamilton's designer diaries for *Santorini* invites us to re-read that play-full suspension of consequences as a pivot that is pregnant with potential relations to the outside. Herein, we explore three ways in which games might enact such play-full pivots: aesthetic and affective experience; interaction as relationality; as well as porous boundaries.

Play-full Pivot: Aesthetic and Affective Experience

> Learning never takes place in the absence of bodies, emotions, place, time, sound, image, self-experience, history. It always detours through memory, forgetting, desire, fear, pleasure, surprise, rewriting. And, because learning always takes place in relation, its detours take us up to and sometimes across the boundaries of habit, recognition, and the socially constructed identities within our selves. Learning takes us up to and across the boundaries between our selves and others. (Ellsworth, 2005, p. 55)

As *experience* is well-worn territory in education, we take a quick detour via Dewey to situate our understanding and use of this term, and to relate it to our key term of reference, *pedagogical pivot*. Through our own play, and in thinking with Dewey (1934), we come to understand the pedagogical potentiality of aesthetic experience as one that fails to provide *the* experience of learning. Rather, a pedagogical pivot differentially expresses what Dewey, in *Art and Experience*, would refer to as *an* experience. A pedagogical pivot produces a singular educative experience, an experience that is "integrated within and demarcated in the general stream of experience from other experiences" and one that "[runs] its course to fulfillment" (Dewey, 1934, p. 35). Imbued with anticipation, development and unity, the experience that emerges from a pedagogical pivot also becomes a distributed moment of thought-fullness and meaning-fullness. The anticipation of *an* experience cannot be disassociated from the notion that board games often pose and provoke questions rather than provide answers, or "an 'answer' that provokes us to keep thinking" (Ellsworth, 2005, p. 59). Board games provide both the drama of learning and a pivot between what is already known and a multiplicity of students' not-yet-thought.

As de Koven (2013) suggests, experience is at the heart of what it means to play games and to play games well: "A well-played game is never the same—never well the same way. As soon as we experience it, we change because of it. It is too powerful an experience" (p. 89). Reading this alongside Ellsworth (2005), these *too powerful experiences* can be thought of as excessive, uncontainable, and acting upon the multiple registers of the body that are never absent in the presence of learning. As de Koven states, games are (like) works of art. As such, we turn to Ellsworth's thinking about aesthetic experience. Ellsworth invites consideration of an expanded understanding of experience at the crux of teaching and learning: "The drama at the heart of education . . . lies in the unanswerable question of the experience of the learning self" (p. 157). For games, this means considering play as being much more than the cognitive understanding and proceduralist enactment

of the set of rules. Or, as games designer and scholar Wehrle (2016) suggests, it means expanding our conception of games as being more than "only a mathematical abstraction that exists virtually in the minds of its players" ("Colonization and Community," para. 3). Rather, it is an invitation to consider the ways in which "all games have an aesthetic footprint" (Wehrle, 2016, "Colonization and Community," para. 3), which comes to curiously engage the learning self-in-the-making through the games' visual art, components, spatialities and temporalities, the ways they are embodied and emotionally felt.

The ways in which play produces aesthetic experience is difficult to express, but aesthetic experience is one of the features of such play-full pivots. As de Koven (2013) attempts to articulate what it means to experience the well-played game, his characterization is provisional and poetic: "When we are playing well . . . we are fully engaged, totally present, and yet, at the same time we are only playing" (p. xxiv). We see this as indicative of the ways in which "some knowings cannot be conveyed through language. They fall in the spaces between the fixed positions on the grids of grammar, definition, and syntax" (Ellsworth, 2005, p. 156). Rather than strictly being known and knowable through signs and signifiers, as signalled above, games might register on our bodies in ways that are affective, embodied and aesthetic. Importantly here, we hold that the provided and produced, partial, contingent and situated knowings, are nonetheless forms of knowing:

> Like an experience of the learning self, aesthetic experience holds the potential for the coming of a knowing, available only through acknowledgment and inaccessible through explanation. Explanation is simply unable to bear the weight of the "knowings" that are aesthetic experiences of the knowing self. Explanation's failures in these realms are of huge consequence for both art and pedagogy. (Ellsworth, 2005, p. 158)

Board games might be thought of as spaces where questions of how to teach and what to teach are not already legislated, spaces in which (al)ready-made knowledges and taken-for-granted knowledge-making processes are challenged as they are always already exceeded by the types of learning that (can) occur there. To the point: in these spaces, cognition is merely one among many ways of learning. Ellsworth's (2005) invitation to take seriously explanation's inability to articulate the knowings that emerge aesthetically is not only a call to examine the ways in which we might problematically detach cognition from embodiment and affect, but also other ways we might make separable and separate knowing(s). In the context of play, making meaning with the diverse types of experiences that differentially emerge and register as and through play is of central importance. Particularly, what is experienced through play does not primarily emerge in spaces of explanation, but rather in-between them. In turn, the ways in which games pivot us towards new relational configurations is a consideration worthy of theorizing:

> A game's affective responses are informed both by the other players and, critically, the game itself, which organizes the relationships between the players and the way that they are able to interface with the game-state. . . . Dependency is an important engine of affect. . . . These structures provide a frame for affective response. In other words, feelings are muted or amplified depending upon a subject's position within a broader structure of dependence. (Wehrle, 2016, "Bodies at Play," para. 2, "Colonization and Community," para. 5)

Aesthetic and Affective Experience with/in Santorini

> As a mathematician . . . I want beauty. I want to express the beauty of mathematics. . . . A well-designed game is experiential art. (Hamilton, 2018, 7:31-7:39, 12:04)

As a mathematician, Hamilton's use of aesthetics in game design initiates students into the aesthetic of mathematics: noticing and expressing patterns through a variety of structures (Chesky & Wolfmeyer, 2015; Steen, 1990). Hamilton explains this aesthetic quality in *Santorini's* design:

> What I bring is the mechanisms. I work on the mechanisms for games really hard. For *Santorini*, the mechanism is bite sized. This is all it is. Take one of your pieces. You move it and around that piece you build. When you're moving, you can move up a maximum of one level. You win whenever you get to the third level. Very, very simple rules. It's the simplicity and the elegance of that system which makes the game beautiful at the start. . . . Simple rules leading to complex, interesting results. (Hamilton, 2018, 2:15-2:45, 13:28-13:29)

Simple complexity is an aesthetic experience of play itself in *Santorini*. Because *Santorini* was designed as "fast to play and fast to learn" (Hamilton, 2011a, 0:34), encountering "interesting results" at the end of a match calls on players to immediately (re)engage in mathematical thinking to experiment with and modify strategies. Whether the end result is a win or a loss, questions of how to become an expert or strategic player continually place the player as simultaneously within and beyond the learning self. Holding up the tension of *simplicity* and *elegance* with *complex* and *interesting* results mimics the fully engaged work of logical reasoning that is foundational for students' subsequent development and use of mathematical proofs.

However, the visual aesthetic of *Santorini* is not undervalued by Hamilton, as he describes the thematic evolution of the physical and visual attributes of Santorini's design:

> I got just normal blocks, white-washed blocks and just printed up Greek nudes on cards with god powers. . . . Gavan [Brown of *Roxley Games*] was taking on the game, he wanted to go this direction and I was quite strongly opposed. . . . I'm glad he got his way. He opened up the game for a totally different demographic: . . . this game is perfect, not just for pure strategy people who want to get that pure strategy feeling. It's also perfect, like, I do play this game down at a kindergarten level. . . . But Gavan's version definitely brings the experience in a small package to kids of I'd say 7, 8 plus. (Hamilton in Eddy, 2017, 10:16-10:27, 49:56-50:56)

As a pedagogical pivot, Hamilton acknowledges that the artwork captivates a wider audience so that even younger children can have *an* experience of play-full problem-solving in the drama of the game.

While engagement through aesthetic elements was part of Hamilton's design process for *Santorini*, this is intimately tied up with the affective response of players' engagement. In creating *Santorini*, Hamilton's intention was simultaneously "to give the joy of a beautiful game for people to play" (Hamilton, 2018, 18:27-18:28) through a game that is "highly enjoyable and fast and interesting" (Hamilton, as quoted in Sentry Box, 2016, 7:48). Students' growth of a productive

disposition toward mathematics (Kilpatrick, Swafford, & Findell, 2001) is fostered through their play-fullness with *Santorini*. Mathematical habits of mind flourish because students can "think about mathematics the way mathematicians do" and "be accustomed to using real mathematical *methods*" (Cuoco, Goldenberg, & Mark, 1996, pp. 377, 378; emphasis in original). This echoes de Koven's (2013) statement that one must be willing to play for a well-played game to emerge, but also that:

> Willingness generates more willingness—that what at first we weren't willing to do we find ourselves seeking out. We become willing to do something that we didn't even feel like doing. We even suspended judgement about whether or not we'll like doing something until the time that we find ourselves doing it. (p. 15)

In the following section, we turn to the multiple ways that games frame interactions (e.g., between players) and how they act as pivots toward relational experiences of the learning-self-in-the-making.

Play-full Pivot: Interaction as Relationality

> At the hands of these designers, pedagogy becomes a dynamic that creates the experience of an idea, of a way of making sense of self, the world and the self in the world. . . . Pedagogy stages encounters with the unthought—encounters with the future as in the making. (Ellsworth, 2005, p. 33)

For de Koven (2013), play-full experiences not only emerge in-the-making, but are concomitantly experiences that are collectively made through our intentional play with others:

> We were each willing to play. We were each willing to play that particular game. We were each willing to play with each other. We arrived at a well-played game because of the way we combined with the game. It isn't something that we made happen. It happened because we wanted it to happen and we were willing to do whatever we could to allow it to become. (p. 8)

How experiences of play register upon the individual cannot be disassociated from the forces, flows and intensities that come to produce play as a relational assemblage: the other players, the social contract whose "guidelines are fragile and fictitious" (de Koven, 2013, p. 11), the many parts of the game (e.g., rules, pieces), and even the realities that the game might come to present us with. As Wehrle (2016) states in the previous section, dependency is the engine of the affective experiences. Games' relationalities are not born out of lack or subordination, but rather of interdependence. Thinking with Ellsworth's (2005) statement at the beginning of this section allows us to take seriously the ways in which space designed for play produces dynamic pedagogies that connect us to the world within[4] and beyond ourselves, and how this shapes what and how we know. This means that such experiences of playing games cannot be considered individualistic or strictly human. We play

[4] While beyond the scope of this paper, there are internal relationalities at play as well. As de Koven (2013) states, games allow for a "dialog[ue] between *the gaming mind and the playing mind*, between this and other games, between these and other communities" (pp. 134-135; emphasis in original). Significantly here, the internal dialogue suggests that when we play to win, there is, importantly, at least two frames of reference that come to bear: the self which strives to win and the self that recognizes that it is but a game.

with others and other-than-humans, with the *here-now* and a multiplicity of *there-thens*. Wehrle refers to the types of relationships produced through play as *affective entanglements.* For Wehrle (2016), games provide a rich subject in which

> the abstract and the embodied come into contact. . . . If a player position is an abstraction (that is, a subject position created by a system of rules), it is one anchored by our affect and rooted in our flesh. . . . Games are bodily experiences. We inhabit the games we play. Our bodies interface with their components. Eyes search those of our opponents. . . . It is this embodied quality that makes the language of affect so useful when it comes to understanding games. So often games, especially multiplayer games, are understood merely as systems of rules. Although this proceduralist lens provides many insights into the nature of games, it tends to obscure the experiences of players and the emotional dimensions of play. Games allow us to occupy new and strange positions of affective entanglement. They offer an exceptional space of unlikely dependencies and interrelations. Indeed, such entanglements have become a hallmark of what a game is. ("Bodies at Play," para. 3)

By way of example, Wehrle (2016) animates this conceptualization of affective entanglements with *The Settlers of Catan.* Particularly, he enumerates a multiplicity of structural elements that create ever-shifting "networks of dependence" (Wehrle, 2016, "Colonization and Community," para. 4) that structure how the game is felt: the game's limited access to, yet need for, all of its multiple currencies (i.e., wheat, sheep, ore, brick, wood); rules governing trade; an ever looming and transparent victory condition; and the risk of losing half one's resources via the robber. Extending the previous pedagogical pivot that explored the aesthetic and affective ways in which games are experienced, and considering how players are placed in relation with one another, with the game, and with the world beyond the game, hints at how "relations are real—and as material—as the social subjects and objects in relation" (Ellsworth, 2005, p. 33).

Wehrle (2016) suggests that the richness of *The Settlers of Catan* comes from the ways in which these rules structure feeling between players, rather than its somewhat generic art, set of components and backstory.[5] However, this is not to say that these latter elements cannot be(come) relational forces that come to shape the play-full experience of games. Extending upon the insight that relations are both real and material, games scholar Jason Begy (2017) suggests that games' materiality is an important force with which games may relationally connect us to the world beyond ourselves. In discussing economic train games,[6] Begy states:

> The materiality of these games is essential: the placing of tiles, the drawing of lines, and the movement of a plastic train are key aspects of simulating the discussed metaphors [i.e., annihilation of space and time]. At the same time, the immaterial aspects of these objects—rules specifying interaction—are also essential in understanding their cultural role. The goal

[5] As Greg Loring-Albright (2015) discusses, this may have to do with not wanting to remind the players that the theme is settler colonialism; and perhaps one of the reasons why it has been re-branded and re-named recently as simply *Catan*.

[6] Economic train games (such as *Age of Steam*, the *18XX* family, and others) are great sites to explore the dynamics of game theory as they are fertile grounds for the calculus of shared incentives.

> here is not to understand games merely as games but as culturally situated material objects that are also games. (p. 736)

Extending this idea, Begy (2017) states that games are a sort of hybrid encounter in which it is not only the human that is enacting play but also its materiality: its pieces, its board, its spatiality, its time. While "rules and processes can be expressive representations, just as the art on the box or the board is", Begy reminds that "how the game is played is as important as its material aspects" (p. 722). Where the former can be read hermeneutically for cultural meanings and significance at an individualistic level, the interdependent or co-constitutive play that occurs through their relational movement can come to co-articulate ideas that are both within and beyond us (see Lenz-Taguchi, 2010). For example, thinking with Begy suggests that economic train games can act as pivots towards metaphors of the *annihilation of space and time* that nascent North American railroads evoked in the 19th century. Depending on the socio-material elements of the design, this relational play potentially pivots us towards different ways of remembering the past, of living in the present, and of conceptualizing a future-yet-to-come. Further, this might allow for the potentiality to come to know already held knowledge otherwise or come-to-know that which was previously unthought. However, the porosity between here-now and there-then, nature and culture, thought and unthought, are not the only binaries that come to break down through the playing of games, as will be explored in the third pivot.

Interaction as Relationality with/in Santorini

> I like the social interaction of face-to-face combat across the table. (Hamilton, 2011b, 1:22-1:28)

We contextualize our knowledge-making of the pedagogical pivot of interaction as relationality within the socio-materiality of Hamilton's design of *Santorini*. In his design of a pure strategy game, the boundary of the relation between the player of the game and the worker (i.e., the pawn) in the game is blurred. This can be seen in Hamilton's (2018) description of a win-state of "*you* get to the third level" (2:34-2:36). In other words, the player symbolically inhabits the builder pawn who is also a material extension of the self. "The fun of the game lies in the fact that you *can* forget yourself" notes de Koven (2013, p. 30; emphasis in original). This embodiment of abstract positionality is further developed with the addition of god cards, such that the dynamic of game play is not only in the player-to-player interaction but also between games—the fluxing initial conditions of each game call on the players to approach each match with fresh eyes (see de Koven, 2013). As Hamilton explains in a design diary,

> What makes each game unique is that players adopt a god or goddess that lets them break the rules in a unique way. If you choose Hades, your opponents cannot step down. If you choose Mars you can destroy a building. (Hamilton, n.d.-b, para. 1)

Yet, Hamilton notes,

> It changes: from beginners for example, beginners will find Pan and Hades extremely powerful. But, as you become more and more experienced, those gods become less and less powerful. And other gods become more and more powerful. What's essential, whenever I created the

> game I knew that I could balance only up to a point. (Hamilton in Eddy, 2017, 46:31-46:58)

Hamilton designed *Santorini* so that the variability that god cards allow in the game play means that players are continually moving beyond what they *know* and *are* and are continually repositioning themselves from game to game. The possibility of (un)balanced god cards draws a player beyond independent movement to interdependent play. Significant for mathematics learning is the logical reasoning called on to develop differing strategies depending on the shifting player-worker-god and player-to-player relations.

The play-full character of board games comes to life through player-to-player interactions. The collective encounter reconfigures not only the imaginative relations of players in a game: it provides a structure in which players constantly alternate between problem solving and posing (Brown & Walter, 1993; de Koven, 2013). We see the completion of a turn as the moment of problem posing—of invitation—to the opposing layer to respond and resolve in the subsequent turn. Extending the earlier pivot, such problem posing is the enactment of affective interpersonal relations. In two-player combinatorial abstract games such as *Santorini*, we come to want to find ways to keep it going, so we "tend to feel some ownership of [our opponents'] difficulties" (de Koven, 2013, p. 18) when we pose problems that are too difficult and are similarly and collectively disappointed if they are too easy. Such problem posing is an art of interpersonal communication and empathy: "Imagine the power available to a group of people who know how to help each other think" (de Koven, 2013, p. 21).

Further, it allows for the reconfiguration of relations within the entanglement of parents, children and mathematics:

> Whenever I'm talking with parents, I tell them their number one job is not to go home and do worksheets with their children. Their number one job is to adopt a board game. And that's because the core of mathematics is problem solving. And games are the most joyous excuse for problem solving. (Hamilton, as quoted in Sentry Box, 2016, 0:30-0:49)

Images of parents *enforcing* children to complete procedural worksheets are held in contrast with parents *engaging* children relationally to "establish a culture of board gaming in the home" (Hamilton, n.d.-a; para. 1). The invitation to the intensities of game play views *Santorini* as a pedagogical pivot that, through interaction, teaches us how to reach beyond ourselves as individuals to learn how to be in relation with others: to learn to play. Significant within mathematics education, playing *Santorini* enables children to reconfigure mathematics beyond the development of procedural arithmetic skills to problem solving, to a relational encounter with what mathematics could be, and simultaneously is, as a discipline.

In the following section, we continue our exploration around the notion that pedagogical pivots hold the potential to (re)open dichotomous lines of thought and being by attending to the ways in which they are always already porous.

Play-full Pivot: Porous Boundaries

> Whatever their medium, each [place of learning] expresses a concern with setting the viewer, learner or audience in motion across boundaries between inside and outside, not with the intent to reinforce those boundaries but to forge participation in the times of spaces of relationality between inside and outside. (Ellsworth, 2005, p. 46)

Thinking with Ellsworth (2005) about play-full pedagogical pivots invites consideration of the ways in which the boundaries of play are both porous and ever shifting. This is not to say that play is without boundaries: "Boundaries help separate the game from everything else" (de Koven, 2013, p. 27). Boundaries are the by-product of play: they happen and shape what comes to bear on play and what does not. Yet, as de Koven (2013) suggests, games are "scripted, yet improvisational" (p. xvi). Extending this understanding that the boundaries we set when playing are not static and immutable, Werhle (2016) invites exploration of the ways in which the rules are (not) the script of play:

> The game's victory conditions provide the central tension of play, and the game's design needs those tensions in order to generate its narrative. Without them, the design sits like a boat in irons. The "game" as an affective form, can only manifest through play. Like stage-acting, this demands players put themselves in a position of vulnerability. But the rules of the game are not a script. Players are at once then both actors and writers, working within a designed space to produce something larger than the space itself. ("Affect goes to War," para. 7)

If there were to be *a* script, it would be an assemblage of (among additional forces) the rules of the game, the materials that guide play, the aesthetics and affect produced, and the social construct we establish in and through play. These all come to shape how play might go and importantly how those who play are co-creators of the game. And yet, boundaries are always open to being reconfigured and co-constituted otherwise. As Werhle (2016) signals, the play-full nature of games does not make them fully open spaces, nor should they be. The closed nature of rules provides the creative constraint that gives play its seriousness and brings those who play into proximal relation: "Rules are the binding force which permits us to be free together" (de Koven, 2013, p. 33). They are a structure that allows us to play with all seriousness.

Along these lines, we believe that it is important to recognize and interrupt the manner in which play and seriousness are often placed in binary opposition. With respect to our exploration, board games are often constructed in opposition to *serious play* and *educational games*. We find resonance with Faidutti's (2013b) comment that "If one plays [only] to learn something, it's not really playing anymore, and the game loses all of its charm and most of its utility" (para. 3). Elsewhere, he expands upon this by stating that the very concept of *educational game* "is a pleonasm disguised as an oxymoron" (Faidutti, 2013a, para. 5). For Faidutti (2013a), games are always already educative. Explicitly naming one as serious is not only an unnecessary repetition (i.e., a pleonasm), it also creates confusion in terms of meanings and has consequences for binary thought and enactment. Specifically, Faidutti invites us to consider *educational games* as an expression that attempts to prop up certain games by negatively defining others: some games are positioned as educational and

others are not. This causes us to interrogate how the term *educational* is deployed. The statement provides a distinction, albeit provisionally, between educational games and games as educational. The significance of this subtle differentiation is multiple. Firstly, as McFeetors and Palfy (2017) echo, students are well aware when games are presented as a candy coating to what is unmistakeably a rote-learning exercise:

> Students are highly conscious of this difference, and are wary of educational games. When a teacher says that they will play to learn, they know perfectly well it's a scam, and react accordingly. They know that the real objective is still to work and learn, that it's not really a game but just a means, and they take the teachers and the school for what they are. (Faidutti, 2013a, "Game as Diversion," para. 2)

Secondly, such illusory practices speak negatively to the work of teaching and learning: that, as the character Mary Poppins sings, a spoonful of sugar helps the medicine to go down. This practice positions school STEM content as inherently unpalatable, to be lived out as uninteresting and not worthwhile. As Faidutti (2013a) states, "Educational games discredit education—it feels like teaching is shameful and has to de disguised as a game. They also discredit games, which become just vague and dishonest mathematical systems" ("Game as Diversion," para. 3). Rather than seeing education as lacking play, and game play as lacking educational value, we think that a creative confluence emerges through treating both as already abundant and enhanced by their cross-product.

Porous Boundaries with/in Santorini

> The connection between mathematics curriculum and board games is totally undervalued. (Hamilton in Eddy, 2017, 23:09-23:16)

The pedagogical pivot of porous boundaries—partially[7] collapsing dualities that previously inhibited meaningful, rich learning—is embedded in many of the design features of Hamilton's *Santorini*. Importantly in his designer diaries, Hamilton addresses directly Faidutti's (2013a) critique of *educational games* as a genre of games:

> You should also avoid educational games. Most of them are painful to play. If the game is fun to play, it's going to be played more, and that's really what you want. The mathematics might be hidden, but I guarantee you that it will be there. (Hamilton, 2011b, 0:46-1:02)

Hamilton's use of *educational games* points to those activities—games which do not pedagogically pivot selves-in-the-making—created to procedurally tell or drill a narrow set of mathematical skills. As the pedagogical pivots have no clear demarcation of where they should begin or end, or of who the desired or desirable learner is, enjoyment is central to the ways in which playing to learn is affectively experienced. As well, teachers place at risk relations with students when

[7] Importantly, and in taking seriously the porous play of binaries, we heed Barad's (2010) call for "a new sense of a-count-ability, a new arithmetic, a new calculus" in which "one is too few, two is too many" (p. 251). This is to say that while binaries are always already co-constitutive, they never become "one": there are still patterns of difference that come to matter in how concepts come to be shaped by their oppositional other. For example, *serious play* and *playful seriousness* are not one and the same.

play-fullness is co-opted with the drudgery of drill. Clearly, Hamilton designed *Santorini* to be a game where the mathematics *will be there* in and through the relationality of the play, suspended both in and outside of the immediate present time. The mathematics is performatively co-constructed in the moment, through action, rather than being prescribed by the designer—making a predetermined, singular cognitive destination an impossibility when playing to learn. Rather than a singular curricular destination, games are "a celebration of problem solving" (Hamilton in Eddy, 2017, 26:41-26:42): the hierarchal binary between procedural skills and problem solving as primary aims in mathematics are not only reversed but are co-constitutive through the porous boundaries of play.

The play-full nature of learning through *Santorini* is embraced in porous boundaries of the rules of play and the conditions of winning, which are always on the move, to produce (almost) limitless problems for players to solve in the uniqueness of each match. In particular, Hamilton explains:

> Once your students are familiar with the regular rules of the game, you may want to experiment with giving them some godly powers. These godly powers allow them to break the rules of the game in a unique way that is associated with the gods of Greek mythology. (Hamilton, 2011a, 3:44-3:59)

Beyond the repositioning of relationality caused by the inclusion of god cards, this game element also introduces creative constraints that cause a player to extend beyond self and knowing to develop alternative strategies in acts of improvisation; a well-oiled and established strategy for one match up may not be effective in another. Elementary students in other reasoning-based game contexts have also reported modifying existing strategies as responses to dynamic play-fullness (McFeetors & Palfy, 2018). These acts of strategic improvisation do not always lead to a win—necessarily so—and the play between *success* and *failure* remains a generative space. In fact, being stuck (Mason, Burton, & Stacey, 2010) or the need for struggle (Jonsson, Norqvist, Liljekvist, & Lithner, 2014) are important phases in students' meaningful development of reasoning mathematically. Furthermore, Hamilton encourages parents to not only play games with their children, "but beat them at a board game" (Hamilton in Eddy, 2017, 23:32) so that they experience failure, because he believes "the best way to unleash creativity in the math classroom is to remove the stigma of failure" (Hamilton, 2018, 16:34-16:39). The porous boundary between success and failure, as well as strategic prescription and creativity, can be fostered in play-full ways as *Santorini* matches are quickly won or lost, with an immediate opportunity to creatively try another strategy.

An Open-Ended Conclusion

> I wonder what might happen to how we teach if we designed pedagogies for ourselves that put us, as educators, in relation to education's outside—if we broke up closed circuits of exchange of ideas, identities, and practices inside education. (Ellsworth, 2005, p. 97)

Prompted by our own curiosities and desires to break up closed circuits of thought within STEM education (e.g., Bazzul, Wallace, & Higgins, 2018), we asked, "What if we, as educators, started from the reality of teaching and learning that so many educational approaches expend so much

energy denying?" (Ellsworth, 2005, p. 166). Accordingly, we engaged in an affirmative critique of sketching out possibilities offered through the use of teaching and learning with games in STEM education. Within this paper, we began by taking up Ellsworth's (2005) scholarship of pedagogically non-prescriptive texts such art, media and architecture, and we positioned board games as one example of such a text. In thinking with Ellsworth, we articulated three pedagogical pivots through which the performative play of games can (re)open learning by placing what is already known with what is not yet. The pivots included aesthetic and affective experience, interaction and/as relationality, and porous boundaries. From this, the ways in which learning occurs beyond strictly cognitive means, is always interdependent and co-constituted by a network of actors, and productively reconfigures taken-for-granted binaries, was animated specifically with Gord Hamilton's *Santorini*. Through our reading of *Santorini* with and through the pivots, we argue that *Santorini* provides a rich pedagogical medium with/in which learners might playfully experience the beauty of mathematics, create a community of mathematics learning, and even recast failure as an important step towards success.

While this paper presents our evolving conceptualizing of the pedagogical potentialities of games within STEM education, we suggest it responds to our opening guiding question regarding what we might glean from games in terms of pedagogy for STEM education. Following Ellsworth (2005),

> We could now step back inside education and ask: What might our encounters with the pedagogical pivot points in the places of learning we have looked at mean to us inside the places of public education? . . . Can we step back inside without leaving these spaces where we do not know, already, what is going to happen here—spaces where there is a chance that I might learn something? (Ellsworth, 2005, p. 97).

As STEM teacher educators and educational researchers, lessons learned through *play-full* pedagogies include considering how we might come to support students in recognizing, articulating, engaging with and unpacking their aesthetic and affective experiences, as well as the relationships through which experiences emerge. We have also been invited to consider the ways in which configurations of learning bring us into relation with self, other humans and other-than-humans, as well as how the learning-self-in-the-making is interdependent or co-constituted within these relations. These concomitant considerations necessarily include the materiality, spatiality and temporality of learning. Experiences and relations connect us with the processes and knowledges already enfolded within the structure of learning, with those beyond, and even with those processes and knowledges not-yet-thought, including relations to STEM concepts both implicit and explicit. Lastly, an important lesson we might take away from such an exploration is to move beyond the sugar-coating of making STEM education relevant (as if one could *add* relevancy; see Barad, 2000). Rather, we might work with ways in which learning is already relevant, leveraging them as sites in which a willingness to succeed is also a willingness to fail; willingness that breeds more willingness.

Pedagogy allows for a rich emergence of knowing and becoming that might allowing for a play-full education to flourish when it is not tethered to a singular curricular destination:

> When we use pedagogy to create potential fields of emergence for learners and for teachers, we risk creating a potential field of emergence for education itself. When we construct and inhabit pedagogies that hold our knowledge as teachers in ways that are responsive to the fact that a learner is an open system—we engage with the fact that, as a human practice, education itself is an open system. (Ellsworth, 2005, p. 166)

To be clear, our goal through this exploration is not to prescriptively respond to the oft-prescriptive discipline(s) of STEM, no matter how productive some approaches might be. Rather, and in line with the theme of the special issue, we envision and pursue STEM education classrooms which might be(come) places of loving kindness: taking seriously the *generous* quality of kindness impels us to pedagogically make space for and hospitably receive the multiplicity of ways that students come-to-know. We are inspired by Ellsworth (2005) to continuously pursue the "space between knowledge already made and knowledge in the making for the children to formulate and to hear—out of wonder, not out of compliance—their own questions" (p. 174).

References

Barad, K. (2000). Reconceiving scientific literacy as agential literacy. In R. Reed & S. Traweek (Eds.), *Doing Science+Culture* (pp. 221-258). New York, NY: Routledge.

Barad, K. (2010). Quantum entanglements and hauntological relations of inheritance: Dis/continuities, spacetime enfoldings, and justice-to-come. *Derrida Today, 3*(2), 240-268. doi:10.3366/drt.2010.0206

Bazzul, J., & Kayumova, S. (2016). Toward a social ontology for science education: Introducing Deleuze and Guattari's assemblages. *Educational Philosophy and Theory, 48*(3), 284-299. doi:10.1080/00131857.2015.1013016

Bazzul, J., Wallace, M., & Higgins, M. (2018). Dreaming and immanence: Rejecting the dogmatic image of thought in science education. *Cultural Studies in Science Education, 13*(3), 823-835. doi:10.1007/s11422-017-9816-2

Begy, J. (2017). Board games and the construction of cultural memory. *Games and Culture*, *12*(7-8), 718-738. doi:10.1177/1555412015600066

Britzman, D. (1986). Cultural myths in the making of a teacher: Biography and social structure in teacher education. *Harvard Educational Review*, *56*(4), 442-457. doi:10.17763/haer.56.4.mv28227614l44u66

Brown, S. I., & Walter, M. I. (1993). *Problem posing: Reflections and applications*. Hillsdale, NJ: Erlbaum.

Byrne, M. (2017). Using games to engage students in inquiry. *PRIMUS, 27*(2), 271-280. doi:10.1080/10511970.2016.119207

Chesky, N. Z., & Wolfmeyer, M. R. (2015). *Philosophy of STEM education: A critical investigation*. New York, NY: Springer.

Cuoco, A., Goldenberg, E. P., & Mark, J. (1996). Habits of mind: An organizing principle for mathematics curricula. *Journal of Mathematical Behavior, 15*(4), 375-402. doi:10.1016/S0732-3123(96)90023-1

de Freitas, E. (2016). Material encounters and media events: What kind of mathematics can a body do? *Educational Studies in Mathematics*, *91*(2), 185-202. doi:10.1007/s10649-015-9657-4

de Freitas, E., & Sinclair, N. (2013). New materialist ontologies in mathematics education: The body in/of mathematics. *Educational Studies in Mathematics*, *83*(3), 453-470. doi:10.1007/s10649-012-9465-z

de Koven, B. (2013). *The well-played game: A player's philosophy*. Cambridge, MA: MIT Press.

Derrida, J. (1976). *Of grammatology* (G. C. Spivak, Trans.). Baltimore, MD: John Hopkins University Press.

Dewey, J. (1934). *Art as experience*. New York, NY: Minton, Balch.

Eddy, J. (Host). (2017, Aug 9). *Episode 40—Dr. Gordon Hamilton, designer of Santorini* [Audio podcast]. Retrieved from http://www.cardboardherald.com/podcasts/2017/8/9/episode-40-dr-gordon-hamilton-designer-of-santorini

Ellsworth, E. (2005). *Places of learning: Media, architecture, pedagogy*. New York, NY: Routledge.

Faidutti, B. (2013a, October 7). Jeu et éducation—Games and education [Blog post]. Retrieved from http://faidutti.com/blog/?p=2347

Faidutti, B. (2013b). Jeux [Blog post]. Retrieved from http://faidutti.com/blog/?p=2244

Fournier, A. (2019, Mar 14). Bored games: Edmonton gamers ditching digital for tabletop. *CBC News*. Retrieved from https://www.cbc.ca/news/canada/edmonton/board-games-capturing-the-imagination-of-online-gamers-1.5056944

Hamilton, G. (2011a, Sept 7). *Santorini* [Video]. Retrieved from https://www.youtube.com/watch?v=JmPzVjdweYI

Hamilton, G. (2011b, Dec 25). *Commercial games 8* [Video]. Retrieved from https://www.youtube.com/watch?v=J8geFOkOUbU

Hamilton, G. (2018, Aug 27). *Creative mornings April 2018* [Video]. Retrieved from https://www.youtube.com/watch?v=orhvNrsHNpI&feature=youtu.be&fbclid=IwAR10CH8BhVm4nowVeldfISQmom5RuabJeUEAA0aeKPY9mnVT3MTyWTolLgw

Hamilton, G. (n.d.-a). *Board games and pencil & paper games* [Web page]. Retrieved from http://mathpickle.com/games/

Hamilton, G. (n.d.-b). *Santorini* [Web page]. Retrieved from http://mathpickle.com/project/santorini

Higgins, M., Wallace, M., & Bazzul, J. (2018). Disrupting and displacing methodologies in STEM education: From engineering to tinkering with theory for eco-social justice. C*anadian Journal of Science, Mathematics and Technology Education, 17*(3), 243-246. doi:10.1007/s42330-018-0020-5

Jackson, A. Y., & Mazzei, L. A. (2012). *Thinking with theory in qualitative research: Viewing data across multiple perspectives*. New York, NY: Routledge.

Jackson, A. Y., & Mazzei, L. A. (2017). Thinking with theory: A new analytic for qualitative inquiry. In N. K. Denzin & Y. S. Lincoln (Eds.), *The SAGE handbook of qualitative research* (5th ed., pp. 717-727). Thousand Oaks, CA: Sage.

Jonsson, B., Norqvist, M., Liljekvist, Y., & Lithner, J. (2014). Learning mathematics through algorithmic and creative reasoning. *Journal of Mathematical Behavior, 36*, 20-32. doi:10.1016/j.jmathb.2014.08.003

Kilpatrick, J., Swafford, J., & Findell, B. (2001). *Adding it up: How children learn mathematics*. Washington, DC: National Academy Press.

Lenz Taguchi, H. (2010). *Going beyond the theory/practice divide in early childhood education: Introducing an intra-active pedagogy*. London, UK: Routledge.

Loring-Albright, G. (2015). The First Nations of Catan: Practices in critical modification. *Analog Game Studies, 2*(7). Retrieved from http://analoggamestudies.org/2015/11/the-first-nations-of-catan-practices-in-critical-modification/.

Mason, J., Burton, L., & Stacey, K. (2010). *Thinking mathematically* (2nd ed.). Harlow, England: Pearson Education.

McFeetors, P. J., & Palfy, K. (2017). We're in math class playing games, not playing games in math class. *Mathematics Teaching in the Middle School, 22*(9), 534-544. doi:10.5951/mathteacmiddscho.22.9.0534

McFeetors, P. J., & Palfy, K. (2018). Educative experiences in a games context: Supporting emerging reasoning in elementary school mathematics. *Journal of Mathematical Behavior, 50*, 103-125. doi:10.1016/j.jmathb.2018.02.003

Odendaal, A., & Zavala, K. (2018). Black boxes out of cardboard: Algorithmic literacy through critical board game design. *Analog Game Studies, 5*(4). Retrieved from http://analoggamestudies.org/2018/12/black-boxes-out-of-cardboard-algorithmic-literacy-through-critical-board-game-design/

O'Donoghue, D. (2011). Doing and disseminating visual research: Visual arts-based approaches. In E. Margolis & L. Pauwels (Eds.), *The SAGE handbook of visual research methods* (pp. 638-650). London, England: Sage.

Sentry Box. (2016, Jul 31). *Dr Gordon Hamilton—Santorini and a mathematician* [Video]. Retrieved from https://www.youtube.com/watch?v=dKMOmkxr7-8&feature=youtu.be

Steen, L. A. (Ed.). (1990). *On the shoulders of giants: New approaches to numeracy*. Washington, DC: National Academy Press.

Wallace, J. W. (Chair). (2019, April). *Reimaging the M in STEM: Mathematical actions for innovative, resilient, and culturally rich communities*. Symposium conducted at the 2019 annual meeting of the American Educational Research Association, Toronto, ON. Abstracts retrieved from https://convention2.allacademic.com/one/aera/aera19/index.php?cmd=Online+Program+View+Session&selected_session_id=1436484&PHPSESSID=546isonmsipi0j4rdtvh47tng7

Werhle, C. (2016). Affective networks at play: Catan, COIN, and The Quiet Year. *Analog Game Studies, 3*(3). Retrieved from http://analoggamestudies.org/2016/05/affective-networks-at-play-catan-coin-and-the-quiet-year/