Game-as-teacher in TGfU and Video-games: Enabling constraints in learning through game-play

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Extended paper based on Keynote address, ACHPER 2009

Brisbane, Australia

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This keynote address will explore how game-play in video games as well as approaches associated with the TGfU model asks us to re-examine traditional assumptions about learning. Drawing on the video game concept of game-as-teacher (Gee, 2007), and concepts such as enabling constraints from complexity thinking (Davis & Sumara, 2006), learning in this address will be framed as emergent, adaptive and self-organizing.

For this paper I understand game-play to refer to the inherent complexity in learning to play a game. It takes place in the action spaces developed by the player(s), constraints in the game set by teacher(s) and/or programmer(s), and the places of uncertainty located within the structure of a game. A game, if structured in such a way as to engage the learner in play, will create the conditions for the learner to adapt their perceptions and actions to the constraints of the game (Davids, Button, & Bennett, 2008; Davis & Broadhead, 2007). Similarly, as noted by Chow et. al, (2007) as learners move beyond the initial co-ordination of movements for a task to develop control they need to develop information-movement couplings. As they state teachers,

> should emphasize keeping information and movements together so that learners can start associate movements with key information sources (e.g., hand movements with a moving ball or movement of a learner in relation to teammates in the situational game). Traditional methods of decomposing tasks to manage information loads on learners inadvertently prevent such information-movement couplings from forming (p. 264).

Creating modified games that preserve the intended tactical concepts of a game as advocated by a teaching games for understanding (TGfU) approach means that learners in the control stage of learning can adapt their game play focusing more on the "tactical aspect of the game in terms of movement off the ball or concurrent movement by teammates in the surrounding environment" (p. 264). This embodied adaptation involves the open energy system of the player exploiting the energy from the environment created by the game structure (Gibson, 1979). Similarly, from a constructivist perspective, learning is more than information processing separated from the context; rather it is an embodied adaptation of the learner where cognition extends beyond the mind as a separate entity to include the body and all its senses (Light, 2009). Traditional and often commonsense notions of learning separate the mind from the body, offering a simplistic notion of correspondence between internal knowing to external reality (Light, 2008). Instead, in this address I will explore learning as an organic process (self-referencing), emergent with others (self-organizing system) and ecological (self-adapting to conditions).

As discussed by Hopper and Sanford (In press), despite the public concerns about videogames, these types of games have been identified as sites of powerful learning. Gee (2003) suggests that game "designers face and largely solve an intriguing educational dilemma, one also faced by schools and workplaces: how to get people, often young people, to learn and master something that is long and challenging--and enjoy it, to boot" (p. 1). In videogames, the game itself is the primary teacher; problems are ordered to teach the player skills and understandings that lead to more complex challenges. In video-gaming, the concept of game-as-teacher refers to learning to play the game through progressions of sub-games known as sandboxes or fish-tanks (Gee, 2007). In other words, a videogame programmer creates the conditions for players to learn from within the game through trial and error, transfer from one experience to another, through conversations with others and "just in time and as needed" prompts in game play (Gee 2005). In this process players learn to create dynamic information-action or perception-action couplings that lead to game success. Game-as-teacher as a core concept in successful videogames can help PE teachers and coaches expand their notions of learning as they enable more learners to enjoy the thrill and social bond of a well-played game.

Game Centered Approaches and Game-as-teacher

Several ideas for the following sections have been adapted from Hopper, et al (2009). Game-as-teacher expands upon the ideas in the TGfU approach and other game-centered approaches. TGfU developed from the work of Thorpe, Bunker and Almond (1986) at Loughborough University in the 1970's and early 80's who proposed a shift from the development of techniques or content-based approaches with highly structured lessons, to a game centered approach (GCA) where students were introduced to purposefully designed series of games or game-like activities that linked tactics and skills within four game categories of associated games. David Bunker and Rod Thorpe created the TGfU model for secondary PE because they were disillusioned with how students left school or club sport programs "knowing" very little about games. They found that the emphasis teachers and coaches placed on producing "skilful" players resulted in players with inflexible techniques, poor decision-making abilities and often an over-reliance on the coach or teacher. They also observed that novice players often became de-motivated from the emphasis on skill development. They argued that learning from the rich context of the game, modified to the ability of the students, rather than programming students with skills to play a game, was a better way to learn.

This dissatisfaction with skill learning before game play, can be traced back to the work of Mauldon and Redfern in the UK for primary/elementary school age children (Mauldon & Redfern, 1969). Similarly in the US, and drawing on the TGfU approach, Griffin, Mitchell, & Oslin (1997) developed the tactical games model (TGM) to help teachers and coaches identify tactical problems and solutions common to games within game categories. In addition, Grehaigne, Richard, & Griffin (2005) drawing from a French tradition of sport pedagogy, suggest another GCA known as a tactical learning decision model focused on team sports. Each of these game-centered approaches (GCA) is summarized in Figure 1. Each approach focused on students' learning first from the social context of a game, purposefully modified to reflect the abilities of the students.

Other approaches to teaching games based heavily on the context of a game include:

1. Play practice by Launder (2001) that advocates using mini games that emphasize the development of game play understanding using principles of shaping play, focusing play, and enhancing play to create play practice progressions.
2. Game sense, developed initially in Australia by Rod Thorpe and a research assistant, focused on the needs of coaches, parents, and teachers who did not know games well enough to implement a TGfU approach. Game sense included a progression of mini-games so that as children met the challenges of one game, the coach then presented the next game. The approach promoting questioning, challenging a coach to move away from being at the centre of the learning process.
3. Games concept approach as a variation of TGfU has been designed to suit the needs of Singapore schools with a focus on students as decision-makers and problem solvers. The games concept approach offers a slightly more structured approach than TGfU by following a pattern of playing modified games, working on the skills relevant to the game and going back to apply skills in a game situation (Light & Tan, 2006).

Mauldon and Redfern Game Education Elementary - 1969	Bunker and Thorpe Teaching Games for Understanding (TGfU) Secondary - 1982	Mitchell, Oslin and Griffin Tactical Games Model (TGM) - 1997	Grehaigne, Richard, & Griffin. Team sports - Tactical Learning Decision Making (TLDM) 2005
1. Design lessons based on developmental stages to games that lead to skillfulness	1. *Modified Game* - Based on games category, game designed to foster an understanding of game form based on the developmental needs of the students.	1. Modified game with conditions placed on the game to ensure students address tactical problem.	1. **Letting students explore** in play context chosen to present them with problems to perceive.
2. Use of a problem-solving approach through game-like situations to highlight tactical solutions	2. *Game appreciation*. Teacher guidance, learners develop an appreciation for how the rules shape the game, and how skills and strategies all influence each other.	2. After initial game teacher asks questions to help students focus on the tactical problem and its solution	2. **Asking open-ended questions** once students perceived problems teacher, with open-ended questions, gets students to debate ideas
3. Teach grouping of skills according to generalized constructs (e.g., sending away, gaining possession, and traveling with an object)	3. *Tactical awareness*. Teacher questioning, learners develop an understanding of important offensive and defensive tactics that assist in gaining an advantage over their opponents.	3. Set skill practice that will help students solve the tactical problem when they return to the game.	3. **Taking part in debate** teacher asking specific questions. Questions focus students on constraints on game play and solutions
4. Plan based on games categories (net, batting and running) as a way of addressing similarities and analyzing game play	4. *Decision-making*. With teacher prompts, learners come to understand how to make appropriate decisions within the game context. Recognizing cues in game situations learners decide "What to do?" in a situation and "How to do it?" as an appropriate response.	4. Teacher establishes performance goal for students for skill practice with teaching cues and extensions to make tasks easier or harder to match varying abilities of students.	4. **Formulation of action plan.** Once students have come up with solutions that satisfy problem the teacher has students practice these solutions to selected performance criteria.
5. Games invention, as a means of giving children choice and an appreciation for the value of rules in shaping the game play for both skills and strategies.	5. *Skill execution*. Learners begin to realize the importance of proper skill execution and hence will have a context from which to develop and/or refine their current skill level as well as understanding how it can be implemented in a game.	5. Teacher sets modified game to help students use learned skills to address the tactical problem. Performance goal for students in the game is set.	5. **Return to play context of game.** Observation and feedback from teacher and refining of game play by players based on action plan.
	6. *Game performance.* Applying the previous steps through performance in modified game against criteria for judging game performance. Game becomes more representative of a formal game.	6. Ensure appropriate closure or ending discussion of the lesson with students.	6. **Back to team game**. All this process leads to generalization of principles of play to other team games

Figure 1 Comparison of critical features of game-centered approaches popularized by the TGfU model

All these approaches critique the traditional skills approach of teaching games, advocating the game, not the skills to play the game, as the critical site of learning. To examine this idea further I propose the game-as-teacher concept. Initially, this concept can be understood by drawing on two guiding principles of game modification by representation and exaggeration suggested by Bunker and Thorpe (1989).

1. Representation refers to mini games developed with the key features and tactical problems of the adult game but played with modifications to suit the learner's size, age and ability, i.e., mini tennis in the service boxes with a sponge ball, or 3 on 3 soccer with two small goals.
2. Exaggeration refers to game structures or rules modified to stress a tactical problem in the game that requires the players to read the situation and apply skills to address the problem, i.e. long narrow court in badminton to stress deep shots and drop-shots.

Each of these principles advocates that the game is structured to enable student learning by situating skill and tactical learning within the game, where the game by virtue of its design and prompts from the teacher, teaches the learner how to play by asking them to consider how the rules affect their ability to play, and how their decisions affect the play of other players. Skill practice is advocated but only when the learner is motivated to learn based on game play, and then within a game-like practice. In GCAs players in a game form a complex learning system. In such a system learning depends on each player's goal of achieving a certain task whilst considering other players and the constraints of the situation (Kirk & MacPhail, 2002).

Complex systems and learning to play games

In complexity systems, learning is seen to occur in a system that is self-organizing, emergent, and adaptive. Complexity thinking allows learning to be described in terms of living and social systems, creating a more dynamic interpretative process for understanding learning as emergent from experiences that transform learners (Richardson & Cilliers, 2001). With complexity thinking, we are concerned with a complex reality that is indeterminable but can be influenced by human action. In a PE lesson, each student would be considered an agent of the system, a "complex structure" that will adapt to an environment that students co-create in part through engagements with each other.

Considering the notion of game-as-teacher, the "game" is set as the condition for the emergence of complex learning. This means that rather than breaking a game into parts (e.g., skills, rules, strategies and tactics) the game is seen as a system of interacting and adapting sub-systems. This whole creates the conditions for the complexity of a game to emerge from learner/task/environment exploration. As Rovegno and Kirk (1995) note, teaching games then becomes "concerned with learners' explorations and attention while performing appropriate tasks within an appropriate environment, an environment that is matched to the characteristics and capabilities of the individual" (p. 461). In relation to videogames, Gee (2005b) comments that "learning is based on situated practices...lowered consequences for failure and taking risks… learning is a form of extended engagement of self as an extension of an identity to which the player is committed" (p. 112). In both these perspectives learning is based on a relational and dynamic way of knowing that is the basis of complex learning systems (Barab & Plucker, 2002).

Drawing on complex learning theories (Barab, et al., 1999; Davis & Sumara, 2005; Davis, Sumara, & Luce-Kapler, 2008; R Light, 2008), I have identified the following characteristics of Complex learning systems that can be applied to games teaching and learning to play video games:

1. Energy exchange between learners, system they create together and the environment (Gibson, 1979)
2. Complex systems made up of nested self-similar simpler systems (Davis & Sumara, 2006)
3. Neighborly interactions based on redundancy between players (Davis, 2008)
4. Diversity for generative possibilities (Davis & Sumara, 2006)
5. Constraints based on simple rules that proscribe system opportunities (Davids, et al., 2008)
6. Skills learned in context, distributed across body, people and tools through participating in comingling roles (Ovens & Smith, 2006)

7. Learners' actions adaptive but structurally determined (Davis & Sumara, 2006)

To define these characteristics I have developed the following auto-ethnographic account that reflects on how complex learning theories have informed my development as a games player, a tennis player, and possibly why I teach games using a TGfU approach. What follows are four anecdotes from my life, each concluded with indented italics piece that connects the anecdote to the characteristics of complexity learning.

Playing Ball Games with my Dad

Keep Up

As a young child of six my first memories of playing ball games are with my dad. He was a keen sportsman playing soccer, hockey, squash and tennis as a young man. I remember playing games with my dad with a bouncy soft rubber ball striking it continuously against a wall or trying to keep it going after one bounce. Dad would always challenge us to go higher than our previous best before we could go in for supper. Often the pressure was on, with mum calling us in to eat, but I always remember getting at least one higher. Sometimes dad would give me pointers but until I struggled I rarely listened to him, I wanted to find out myself how to do it.

> *From a complex learning system perspective my initial learning was very much a co-mingling with my father's ongoing history of playing sport. There was an intimacy through our entangled play as we adapted to each other's emergent participation* ***with skills developing in games context****. Learning was characterized by trial and error correction with successful actions repeated, adopted and continuously adapted.*

Shoot Out

When we played against each other games were invented using structures in our environment. A ball, a large barrel and a bucket could soon be incorporated into a shoot out game. I always had the bucket. As I grew older the games became more sophisticated, now a shoot out game with a plastic soccer ball would have goals formed. My dad six foot four and me five foot nothing would kick the ball into the goal with the imaginary crossbar at head height; my goal was therefore lower in height. Initially, when we started to play my goal was also shorter in length. As we played I learned to dive, catch and step into my kicks. I think my dad made suggestions but mostly I remember copying what I saw him do when he beat me. If my dad started winning he would increase the length of his goal to encourage me to try again and kick to spaces. I suspect he held back, but I had to score to win, and I did. Soon the game rules changed and I started getting a lead. My dad would suggest that my goal would be increased in size or reduced the size of his. Sometimes I would argue because I wanted to win. But gradually I realized that I wanted the game to be close, for play to happen, not just me winning. I remember a great sense of accomplishment when I beat my dad but I mostly I remember always playing a close game.

As noted in complex systems, there is an ***exchange between environment and the agents that form a system****. As players of the games we created a system where there was a rapid and spontaneous energy exchange between the game environment we created and ourselves. The games were diverse and produced huge possibilities with* ***the difference between us as players offering even more generative possibilities*** *as the game structures were adapted to our play. The games were* ***structurally determined in a way that afforded both of us as players the opportunity*** *to succeed. As players we* ***negotiated the rules based on the common intent*** *of creating a game that was close. In a close game we both knew that play would happen and that the outcome could not be anticipated.*

Topspin Backhand

As a young teenager I played tennis in tournaments. I never really had a coach like the other boys, my family was not wealthy, but I was a determined player with a big forehand, fast serve and a slice backhand. My style of play was like my father's. As I played at higher levels the boys I played hit the backhand with topspin and I would often lose close games to highly ranked players. On vacations my dad and I would play tennis. Usually I could beat him in a game of singles, but I could not hit a topspin backhand. So we made a rule, I could only win points with a backhand. Initially I lost and was frustrated, but we practiced the backhand, experimented with the stroke, grip change and follow-through, with balls being fed to my backhand side. When we returned to the game

I started to win points with my backhand and the game became close. By the end of the vacation I had developed a reasonable backhand stroke with the ability to hit over the ball, I still favored the slice, but unexpectedly in a game now I would occasionally flash a backhand topspin for a winner.

> *In all the games my father and I created we freely manipulated the constraints of the game, changing space, equipment and conditions of play. However in this example we actually used the constraints to enable skill development. By* ***setting the simple rules we proscribed*** *the backhand behavior allowing the topspin* ***skill to unfold from the bottom up****, from trial and error, to its selective application within the context of a game that was close.*

"Still got the touch"

As young man I competed in provincial and national tennis competitions. As my father got older he needed knee operations and gradually lost the ability to play tennis. He often used to come to tournaments to watch me play. The last time he played tennis was when he was 68. I needed to hit some balls for a tournament and had nobody to practice with. He came on the court dressed in sandals, slacks and a cotton cardigan. Using my spare racquet Dad stood at the net and volleyed the ball I hit to him. After a few rallies he started volleying the ball to spaces, sometimes dropping it short, I scrambled and returned the ball to his racquet, he enjoyed that and I remember him remarking, "Still got the touch." Then similar to when I was a child we created a game.

My dad, not equipped to move, stood inside the service box; this was his court. I stood behind the base line. I had to cover the singles court and the doubles tramlines. We then played a tiebreak. If I fed the ball into play, Dad, would often hit a winner. So to allow the game to get going we adjusted the rules so that he had to feed the ball into play and then after my return the point would start. I did not hold back. I do not remember who actually won the game but I remember the rallies being long and running a lot to keep the ball in play. I remember hitting backhands and dad reminiscing about that time in Spain when we created the backhand game. I also remember whipping the ball at my dad, probably my best chance to win a point, and then Dad with glee instinctively using a backhand volley to drop the ball short in space. Even now when I see my father he remembers the last time we played tennis, recalling the backhand drop shots and remarking, "Still got the touch."

> *This last anecdote shows how the* ***nested self-similar nature*** *of the games that my dad and I played offered the key organizational features of tennis. The* ***common experiences (redundancy)*** *of playing our invented games allowed us to create a* ***game that adapted to our structurally determined abilities****. Similarly to when I was a young child, the spontaneous* ***energy exchange between the game environments we created and ourselves*** *re-invigorated my father, allowed him to call on the skills learned through his youth as we once again played a game of tennis.*

Reflecting on my own experience and drawing on complexity thinking I advocate a third principle of "modification by adaptation" to add to Bunker and Thorpe's modification by representation and exaggeration. In "adaptation" the game is modified to increase the challenge to a successful player based on the outcome of the previous game. Changes can be made in relation to the constraints of the game such as space, scoring, rules conditioning play or number of players, in order to ensure the outcome of the game is close, for the unanticipated to happen through game play.

Video game play and complex learning

In this next section I will explain how successful videogaming such as role-play games, simulation games (e.g., race car driving, flying), sports games (e.g., football, soccer), or shorter puzzle games (e.g., Tetris, Bejewelled) realize these characteristics of complex learning and help us apply them to game centered approaches. As noted by Gee (2007), the "teacher" is predominantly the game itself, created by a behind-the-scenes programmer who has attempted to create a game environment, through many trials and revisions, that actively engages the player in meaningful experiences related to the game.

An Example of learning to play Guild War: An application of complexity learning theory

To help clarify how complexity learning emerges in video games, examples from a novice player learning to play Guild Wars will be shown. Guild Wars is an on-line multiplayer, role-playing game within an episodic series (ArenaNet, 2005). Hosted on ArenaNet servers, Guild Wars provides two main modes of game-play: (1) a cooperative role-playing component; and (2) a competitive player vs. player component. The games portray the history of a fictional fantasy world called Tyria. Campaigns in the game focus on events in disjoint sections of the world, but roughly parallel in time (Wikipedia, 2008).

Customizing Game-play: Identity through selecting structurally determined actions

As players engage in videogame play, they find that "the virtual worlds of games are rich contexts for learning because they make it possible for players to experiment with new and powerful identities" (Shaffer, Squire, Halverson, Gee, 2004, p.6). As Gee (2005) further suggests, "humans think and understand best when they can imagine (simulate) an experience in such a way that the simulation prepares them for actions they need and want to take in order to accomplish their goals" (p. 24). They imagine themselves as individuals capable of the actions accomplished by their virtual characters. Figure 1 shows the customizing options a player has for their avatar. Different accessories and characters offer different potential game-play attributes such as casting spells, fighting or healing other players. As players select from the tools and characters available they start to own their identity, they have selected a way of playing.

Figure 1 Customizing your Guild Wars character

As they play through their avatars in the game, they 'live' the life of another, they recognize how their choices have structurally determined their game-play potential, they see how others interact with them, how they are valued, and how respect is earned. By virtue of their choices they offer diversity to the system of game players and they become aware of how their avatar learns skills they will acquire to solve problems.

Purposeful Engagement: Energy exchange through neighbor interactions and feedback loops

Videogames, if they are good ones, allow for diverse players, with varied skills, interests, and background experiences to come together in a meaningful way to achieve a common goal. Whether they are on the same team or in competition, the goal is to engage in activity that is purposeful, meaningful and challenging to all of the players. Players would not spend hours and hours of their time playing games (to the concern of parents and teachers) if they did not find purposeful engagement and pleasure in the activity. And embedded in that engagement is powerful learning that enables connection to other situations and challenges. Videogames are activities that are "personally meaningful, experiential, social, and epistemological all at the same time" (Shaffer, Squire, Halverson, Gee, 2004, p.3).

Problems are created in the game through constraints that allow a trial and error learning process that, as Gee (2007) describes, has to be "pleasantly frustrating" (p. 36). For the players it feels difficult, but doable, with any effort paying off as the players get feedback about their progress even if they do not succeed, they learn to read the game play space. In this way learning is emergent from repeated trials and recognition of success. For example, the avatar in Figure 2 is discovering the limits of his world, he cannot go through the large iron gates, but he wants to get into the village. So after a few frustrating attempts the player starts to recognize the map with an arrow showing him the way to go. This exchange channels the player's energy into exploring more of the game play space, challenging him to find another way into the village.

Figure 2 Pleasantly frustrating experience

A critical element to the learning process, especially with role-playing games like Guild Wars, is the characteristic of neighborly interactions, offering "teacher-like" comments as part of ongoing feedback loops within the system (Clarke & Collins, 2007). Gee (2007) refers to this idea, suggesting that "games almost always give verbal information either 'just in time'—that is, right when players need and can use it—or 'on demand', that is, when the player feels a need for it, wants it, is ready for it, and can make good use of it" (p. 37-38). In the video game shown in Fig. 3, the avatar gains information from another character directing him where to go next and what to look for to gain spells. Feedback information within the game structure increases the player's awareness of what will lead to success and completion of a challenge. Skill learning is then distributed across activity in the game, across roles, tools and other characters in the game.

Figure 3 Neighbour interactions from characters in the game give "information as needed" and "just in time"

Liberating constraints in Fish tanks and Sandboxes for purposeful repetition

In videogames problems are well-ordered to teach the player skills and understandings that lead to more complex challenges (Gee, 2005a, 2007). The game is programmed in such as way as to scaffold learning at a rate that the player (whether novice or expert) can manage. Gee (2007) refers to this concept as sandboxes (like exaggeration games in TGfU), where players can play with "risks and dangers greatly mitigated, they can learn well and still feel a sense of authenticity and accomplishment" (p. 39). Sandboxes refer to bounded constraints placed on the player that limit their options and reduce challenges. These sandboxes exaggerate certain game-play problems, allowing players to develop certain skills that create more in-depth understanding of how to play within the game rules, enabling more advanced play later in the game. The repetition builds player confidence that fosters advancement to more challenging situations.

Figure 4a and 4b show the avatar discovering through trial and error how to cast a spell that kills the monster. In Fig 4a the monster does not fight back, just looks vicious. As the avatar succeeds at casting a basic spell he receives two more different spells to choose from (see glowing icons on the dashboard in the image). Each spell offers a different killing technique that will be needed for more challenging antagonistic creatures.

In Fig 4b the avatar has to face an opponent who fights back, resulting in a loss of health points, however with repeated use of his basic spell he eventually beats the opponent, but in a tight battle. The player then realizes that the new spells may be useful next time.

Figure 4a Learning to fight acquiring new spells

Figure 4b Opponent becomes a little more difficult to kill

As players advance in the game they learn to make sense of the map and compass in relation to views they experience. As Gee (2007) notes, the sandbox experiences, which are designed for player success, lead into what he calls fishtanks (like representation games in TGfU) that denote "simplified systems, stressing a few key variables and their interactions, learners who would otherwise be overwhelmed by a complex system...get to see some basic relationships at work and take the first steps towards their eventual mastery of the real system" (p. 39). As shown in Fig. 5, the player makes sense of variables in the self-similar structures created by the emerging complexity of the game. The map corresponds to the world he sees, his path is tracked and markers on the compass highlight targets.

The game affords opportunities for the players to take advantage of the environment through exploration encouraging randomness of responses from the players. Such responses can create chaotic events as players encounter different monsters and environmental challenges leading to his avatar being killed. However, each event leads to generative possibilities as learning emerges, each encounter leading to new insights and skills needed to overcome a challenge. The game structure offers decentralized control over the player as they adjust to the rules and the conditions of the environment.

Figure 5 Fish tank view of the system

Decentralized control leading to bottom-up organization: Skills learned in context

Gee (2007) proposes that the player's mind also works like a videogame; productive thinking is like interacting in a game scenario or running a simulation rather than about forming abstract generalizations separate from experiential realities. As Gee continues "effective thinking is about perceiving the world such that the human actor sees how the world, at a specific time and place (as it is given, but also modifiable), can afford the opportunity for actions" (p. 25). This idea is very much related to complexity thinking that advocates a bottom-up notion in learning. Such a notion means that the game-world created through the player's engagement creates a mutually affective relationship to subsequent experiences in the game, where their actions are altered by virtue of their descriptions and engagement. In this way players' perception of possible actions emerge as they couple actions to the recognition of certain patterns in the game-world, a world their actions create.

In game worlds, “learning no longer means confronting words and symbols separated from the things those words and symbols are about in the first place… learners can understand complex concepts without losing the connection between abstract ideas and the real problems that can be used to solve” (Shaffer, Squire, Halverson, Gee, 2004, p.4). As a player engages in game-play, they draw upon previous play experiences, eliminating possibilities that did not work, selecting alternative choices, determining the result, and then moving on to the next problem-posing interaction. As they select possible moves, they learn what works, what are the best choices, and they develop theories (albeit implicit) about the reasons for some choices being better than others. And although the goal is to progress as far as possible through the game, there is the knowledge that if they ‘fail’, they will be given more opportunities to try again, this time as more informed and experienced players.

In Figure 6 the avatar has gained many new skills, each from successful missions, the avatar is working with a partner who demonstrates how to deal with a difficult opponent. As an added challenge the avatar is in a maze of catacombs full of toxic gas, so he has only a limited time to complete the mission. In this particular experience the avatar dies many times before collecting enough information, from partner and from trial and error, to figure out how to succeed.

Figure 6 Multiple sources of information built up over time for taking on a mission

Learning in context means the player’s avatar is engaged as an agent in the activity of the video game with other agents (avatars). Through trial and error recognition, the player learns that knowledge is distributed across persons and particular context (Barab &

Plucker, 2002; Ovens & Smith, 2006). As avatars take on legitimate roles they develop, through adaptation, skills to enable the activity of the videogame system.

Example of complex learning in Tennis using TGfU

In this section I will focus on how the teacher can teach using a TGfU approach in order to engage students in complex learning. A TGfU tennis lesson was video recorded to capture events to analyze them in relation to complex learning. The intent of the lesson was for the learners to develop their consistency in keeping the ball in play as they learned ball placement in the court and the related positioning. The focus on consistency, placement and positioning promoted the context for the learners to develop their skills in hitting forehand and backhand drives.

Customizing Game-play through selecting structurally determined action potentials

As shown in Figure 7, and similar to Figure 1, the players are offered an array of equipment to use to customize their tennis game play such as different rackets and a variety of balls of different weight, size and construction. In game-play learners could decide to use a one-touch control hit of the ball before sending it back into play. In selecting different potential game-play options the learners started to structurally determine their own tennis identity, way of playing. The teacher needs to acknowledge in their teaching practice that the learners' responses are dependent on, but not determined by, environmental influences. What the learners bring to the lesson, mediated by their choice of equipment and game play options, interacts with the conditions set by the teacher, affording students' different learning opportunities.

Figure 7 Modified racquets and balls to customize game play

Purposeful Engagement: Energy exchange through neighbor interactions and feedback loops

In our particular example, the teacher initially taught the "Castle" game (shown in Figure 8a), a representational type game, creating a game-world that students would find purposefully engaging and related to tennis. As noted by Hopper (2007), the aim of the castle game is to hit the pylon to score. The following three rules create the enabling constraints for initial game play: (1) the ball must bounce once (so it can hit the target); (2) the ball must be hit above head height (height allows time to get to ball); and (3) the ball is hit by players alternately (tennis-like relationship).

Figure 8a "Castle" game for two players

In the Castle game the students are given the option to use hands to catch and toss the ball, to grip the racquet from the throat or use a short-handled bat. These choices provide the opportunity for students to gain some control over how they play the game. As noted in the videogame example, students' interest is maintained by actively engaging them in problem solving situations related to tennis, creating a trial and error learning process that is "pleasantly frustrating". Initially, the constraints of the Castle game focus the players on understanding how to move in preparation for hitting the ball as they anticipate the ball flight. The teacher sets problems for the students by asking, "How should you stand to get ready to hit the ball?" and "Where do you go after sending the ball to the castle?" Initially, the wide-base, staggered feet set-up for movement, labelled "base", is discussed as students see the need to move in every direction with push-off movements.

After students play the game again, an *emergent* realization in relation to the "Where do you go..." question soon comes as they answer, "On the opposite side of the castle from my partner." This answer means that the player knows where to go even before their partner plays their next shot. This simple action represents a "decision making" movement for the players that gives them time to play the next ball.

The pattern of play then becomes: hit, base, look to make a decision movement, then set-up for the next ball. Initially, players in the game have difficulty getting the movement patterns coupled with striking the ball, but with feedback from the teacher ("as needed" and "just in time"), guided questions and through observing each other, the players learn to play with tennis-like actions. At the start of a TGfU lesson the teacher must facilitate neighborly inter-actions between learners through feedback, demonstration and encouraging purposeful interactions. This enables the players to inter-act as a system of learners not as individuals learning to play tennis.

Liberating Constraints in Representation and Exaggeration games for purposeful repetition

The tennis-like actions in the Castle game, the movements of base and decision making, striking the ball repeatedly, allows the learners to develop a tennis identity, a sense of how to play the game of tennis. As shown by Figure 2b, these two movement actions can be practiced by students on their own in a shared space, in a "keep-up" game (exaggerating consistency), as they try to hit the ball repeatedly just above head height after one bounce. As in the Castle game, the players practice moving to the anticipated placement of the ball (decision-making) and setting up with a base position. These repeated cycles of practice, made meaningful by the Castle game, allow the movements to become embedded in the game-play. The teacher can use this context to ask, "Where is the best place to make contact with the ball?"

Figure 2b "Keep up" game learning to keep the ball going after one bounce

Again, through trial and error correction, students soon comment that the best place is around waist or knee height in front of the body; known as the hitting zone. Watching others and practicing in this “keep-up” game (like "sandbox" notion in videogames) students learn to make adjustments as the ball bounces. These “adjust” movements alter their base position as they prepare to strike a falling ball in front of their body. Further discussion can also be encouraged about how to grip the racquet in order to facilitate successful play. In this way the teacher focuses on creating the conditions, with feedback loops shifting the learners back and forth from in-control (stable) to out-of-control (unstable), necessary for them to experiment, finding responses that allows them to exceed themselves as players.

When players return to the Castle game there is rapid improvement. The players’ shared experiences allow joint activity that creates a learning system. This game-play happens because each player is adapting to the flight of the ball and to the position of the target as the ball is sent back and forth. Finally, to distribute the learners’ play across all the main components of the game the teacher can ask, “What do you do as the ball is struck by your partner?” This question asks a player to judge when their partner hits the ball. As the partner hits the ball, the player wants to do a jump step, putting their body in motion, allowing them to cover the target area as the ball leaves their partner’s racquet. The addition of this cover action fully connects the players to the flight of the ball, the target and the actions of each other, maximizing their capacity to keep the ball in play, aiming it towards the target. This relationship creates an energy exchanging system between the players and the game-play environment. The beginning of each player’s forehand skill emerges from repetition motivated by the interactions with other players, constraints of the game, and the teacher prompts.

Sticking with a videogame comparison, the base, decision, cover and adjust actions learned in the previous games allow the players to engage in system thinking where similar actions from the Castle game transfer into playing in the tennis court and over the net. After playing in the court the players find they can hit with the forehand but have limited ability to control the ball with their backhand. The question often raised by the students is “How do you hit the ball with the backhand side of the racquet?” Figures 3a, 3b and 3c show a progression of play, practice, then play again, that transfers into a tennis-like game where the backhand is needed.

Initially players try to cooperatively play the “backhand goal” game in Figure 3a. In this game one partner throws from the net between the goal targets for their partner to hit back using the backhand drive, recovering to the side after every hit. After three successful hits caught by the feeder, the goal is moved further back, increasing task difficulty; the aim of the game for the pair is to be able to strike three backhands from the baseline. At first players struggle to strike the ball consistently as they try to transfer movement patterns and racquet action for a backhand; players find ball contact challenging in this context.

To solve this problem a skill progression for the backhand is taught. In Figure 3b players stand square to the net as they are shown a backhand grip with the fleshy part of the thumb on the back of the grip. As a liberating constraint this set-up allows the whole body action of knee bending and then extending, emphasizing the racquet strings brushing the back of the ball. One partner simply tosses the ball just over the net, allowing the other partner to bend and brush with a “J” action to strike the ball back. As a "feel" for this movement is gained, the striking players extend their arms after they brush the ball. Continuous practice with a partner coaching the actions, periodically swapping roles, enables connections between players allowing dynamic adjustments to the conditions as players learn from each other. Eventually, after the players have practiced they return to backhand “goal” game shown in Figure 3c. As can be seen comparing image 3a to 3c there is rapid improvement in the form of the backhand with the striking player showing more mature form and progressing back to the baseline.

(a)


(b) 

(c) 

Figure 9 Backhand progressions from “backhand goal” game, to practice and then back to game

The capacity of the novice tennis player to engage in system thinking, appreciating how a skill practice will related to the game of tennis, creates the desire to learn more. The teacher needs to design enabling constraints that determine the balance between sources of coherence, following a task progression that allow learners to maintain a focus, and sources of difference, degrees of freedom in using a skill, that compel the collective of learners to adjust to each other as learning emerges. The critical role of the teacher in the games lesson is to focus learners on the emergent moments when their actions in the modified games successfully ‘fall together’ in ways that cannot be fully anticipated but apply diectly to the context of game.

Decentralized control leading to bottom-up organization: Skills learned in context

As players’ learning is transferred from the Castle game to the court space, they are ready to play the type of game highlighted in Figures 10 and11. With the option of using a dense sponge ball that flies slowly but bounces like a tennis ball, the players play in service boxes, except they start the play in a quarter of the service box. The struck ball is good if it goes over the net and lands in the designated quarter of the service box court. If the ball lands out or in the net then the other player increases their court size. In Figure 4 the left side player won the first point so her space has increased.

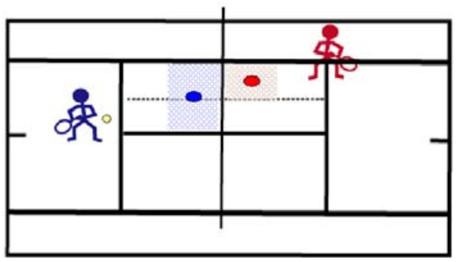

Figure 10 Playing "Space adapt" game in court space that changes based on point won

Figure 11 Players transferring learning into the game

In this adaptation type game, the players play to win the point, but the court they cover increases in size making winning the next point more difficult, the goal being to win four points. As can be seen in Figure 11, the far player has a dot marking a smaller court to cover but a larger court to aim at, indicated by the other spot on the line dividing two areas. This gives him confidence to hit with his backhand transferring the practice in the previous exercise in Figure 3 into the game. Players can also be encouraged, as needed, to use the one-touch to control the ball before striking the ball over the net. The game creates a self-organizing learning system where students draw from the previous games using the base, decision-making, cover and adjust movements as they strike the ball in the hitting zone. Prompted by the teacher, players cover their target area and, if possible, strike the ball away from the opponent as the court increases in size. As the game develops, the players engage more in game-play, becoming more decentralized from the teacher as they become engaged in the game that adapts to their play. This adaptation type game allows players of diverse abilities to interact and be immersed in playing a game.

Teachers need to design lessons that acknowledge skills as an expression of distributed knowledge located in the game-play. If the outcome of the game cannot be fully anticipated then the players are more likely to engage in game-play where their actions, within the constraints of the game, challenge their opponent. The adaptation game adjusts automatically to the players, modifying game constraints, increasing the challenge to a successful player based on the outcome of the previous encounter. This process means that that game maximizes its potential to act as teacher with players learning in association with the activity of the system; in the space adapt game they learn to hit to the opponent’s game-play spaces and to cover the opponent’s target area as previously learned in the Castle game.

Conclusion: Enabling constraints in modified games

The game-as-teacher concept applies to how I learned as a young child to play ball games by playing the game. In addition, this concept is core to how successful videogames model create emergent learning from trial and error correction and hints from the programmer, as players create information-action couplings for successful game play (Davids, et al., 2008; Gee, 2007). Similarly, game-as-teachers informs GCA approaches advocating learning within a social system that encourages learners to continuously adapt their actions to the constraints of the game.

In conclusion, games should be programmed with constraints in such a way as to scaffold learning at a rate that the player (whether novice or expert) could manage the information-movement demands. These enabling constraints allow players to develop skills that create more in-depth understanding of the game rules, leading to more advanced play later in the game. Representation or “fish tank” games create self-similar game structures that feed into the advanced game. Exaggeration or “sandbox” modified game/tasks stress tactical problems in the game that requires the players to read the situation and experiment with how to apply skills to address the problems. And finally, to fully realize how game-as-teacher applies, modification by adaptation means the game can be designed to automatically change, like a video game, to challenge a successful player based on the outcome of the previous game form. In adaptation games eventually the outcome is close as play emerges, with the ultimate goal of playing being something more than winning. I believe that if such games are taught in PE, players will be engulfed in, and want to experience again and again, the complex interactions of players, space, rules, equipment and shared intents.

Acknowledgements

Thanks to Jannelle Smith, Raechel Marchand, Carly Groot, Nicole French and Darryl Adams for participating in the TGfU club that generated the images for this paper and helped further refine the ideas presented.

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