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The Role of Nonlinear Pedagogy in Physical Education

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Abstract

In physical education, the Teaching Games for Understanding (TGfU) pedagogical strategy has attracted significant attention from theoreticians and educators alike because it allows the development of game education through a tactic-to-skill approach based on the use of modified games. However, it has been argued that, as an educational framework, it currently lacks adequate theoretical grounding from motor learning perspectives to empirically augment its' perceived effectiveness by educators. In this paper we examine the literature providing the theoretical underpinning for TGfU and explore the potential of a nonlinear pedagogical framework, based on Dynamical Systems Theory, as a suitable explanation for TGfU's effectiveness as a strategy in physical education teaching. The basis of nonlinear pedagogy involves the manipulation of key task constraints on learners to facilitate the emergence of functional movement and decision-making behaviors. We explain how interpretation of motor learning processes from a nonlinear pedagogical framework can underpin educational principles of TGfU and provide a theoretical rationale for guiding implementation of learning progressions in physical education.

The Role of Nonlinear Pedagogy in Physical Education

Introduction

Educators are challenged to provide learning experiences for students that are realistic and which present opportunities for 'knowledge construction' to be generated by the learners themselves. Windschitl (2002) argued that learning, particularly with implementation of constructivist instructions in learning contexts, would be optimized if students were engaged in complex and meaningful problem based activities as well as applying knowledge in diverse and authentic performance contexts. These ideas have some relevance within the domain of physical education, since in recent years teaching approaches that attempt to improve students' involvement in meaningful and context relevant learning have emerged.

In terms of curriculum study, value orientations have provided the foundations in the understanding and analysis of curriculum development (Jewett, Bain & Ennis, 1995). One of the most prominent value orientations in physical education is disciplinary or subject mastery where practitioners attempt to teach perceptual-motor skills through verbal explanation, demonstration, practice drills and simulated game play (Jewett et al., 1995). However, there are other significant value orientations in the study of education and curriculum, such as the learning process approach, which highlights the importance of how learning occurs, as well as ecological integration in which the learner is seen as an integral component in the learning environment (see Jewett et al., 1995). Different teaching styles and approaches, like command, practice and problem solving have emerged from these different orientations in curriculum development. Based on these different value orientations, in the past decades there has been increasing interest in examining the merit of popular pedagogical practices including the Teaching Games for Understanding (TGfU) approach for games teaching in physical education.

Teaching Games for Understanding (TGfU)

The TGfU approach was originally developed because of dissatisfaction with how motor skills were taught in schools in the early 1980s. Bunker and Thorpe (1982), who first conceptualized TGfU, highlighted the limitations of traditional approaches to games education. Traditional approaches were viewed as being technique dominated, following a series of highly structured lessons in which a list of movement skills was sequentially taught to groups of learners (Werner, Thorpe & Bunker, 1996). Such pedagogical approaches have tended to over-emphasize (a) the isolation of movement skills from performance contexts during practice, (b) task decomposition during learning, and (c), the role of repetition in skill practices to allow learners to transfer acquired technical skills into game situations (Rink, 2005). The dominance of such a technique-oriented approach to games education led to suggestions for a greater emphasis on developing the cognitive and decision-making skills of students in physical education classes. Specifically, it has been observed that (a) a large percentage of children have achieved little success as a result of emphasis on component skill performance, (b) the majority of students leaving school understand very little about games playing, (c) there has been a development of putatively technically sound players with poor decision making capacity, (d) such practices emphasized the development of players who were teacher/coach-dependent, and (e) there was a failure to develop ‘thinking’ spectators and knowing administrators at a time when games (and sport) are an important form of entertainment (Hopper, 2002; Thorpe, 1990).

The Rationale for TGfU

The focus of TGfU is to design learning experiences for individuals to acquire tactical skills of the major games through playing modified versions of a target game, considered suitable for their physical, intellectual and social development. Because TGfU emphasized tactical understanding being developed before movement techniques, it was seen as an approach for redressing the balance towards understanding the ‘why’ of games playing performance before the ‘how’ (Hopper, 2002; Werner et al., 1996). To exemplify the focus on tactical awareness, Thorpe (1990) pointed out “The basic philosophy of games for understanding is that a person can play games with limited techniques and, even with limited techniques be very competitive.” (p. 90). Unlike traditional approaches centered around learning specific movement skills and acquiring techniques associated with these skills in isolation, before using these skills in adult versions of a particular game (Turner & Martinek, 1995), TGfU is student-centered with the learning of both tactics and skills occurring in modified game contexts (Griffin, Butler, Lombardo & Nastasi, 2003; Hopper, 2002; Thorpe, 2001). In this sense, modified games are practiced to enhance understanding and awareness of learners in full game contexts.

There are four game categories in a TGFU approach including (a) target, (b) net/wall, (c) striking/fielding, and (d) territory/invasion games (Werner & Almond, 1990). A TGfU lesson typically begins with games in one of these categories, modified to encourage students to think about a specific tactical problem targeted in the lesson (See *Figure* 1 for the Games for Understanding Model). The modified game usually involves adapting equipment, the playing area or the rules to constrain or guide learners towards solving the targeted tactical problem. The introductory game is followed up with questions and explanations by the teacher on the tactical implications of the tactical solutions being practiced. An example of a TGfU based lesson will be shared later in the paper to further exemplify the processes underlying the TGfU approach.

****Figure 1 near here****

Game appreciation is emphasized to enhance understanding of the rules and the nature of the game to give the game its shape. Tactical awareness is also encouraged to challenge learners to solve problems posed in the game and to gain relevant knowledge for performance. This initial emphasis is followed by developing decision making, which leads to knowing ‘what to do’ and ‘how to do it’ in relation to specific tactical situations. Skill execution and performance are then assessed by observing the outcomes of decisions as they are executed by learners during actual game play (Turner & Martinek, 1999; Werner et al., 1996). To summarize, the key features about TGfU are its’ student-centered approach and the flexibility in manipulating constraints in modified games to teach tactical knowledge and subsequently skills related to specific tactical concepts (Griffin et al., 2003; Hopper, 2002).

Empirical Support for TGfU?

Although the TGfU methodology was proposed by Bunker and Thorpe (1982) as an ideal alternative to traditional technique-based teaching approaches, empirical studies have obtained mixed conclusions about the validity and merits of a TGfU approach. Much of the research on TGfU has utilized a quasi-experimental design in which learners’ knowledge has been measured using a knowledge test and game play examined using a protocol focusing on the control, decision as well as execution components of performance. In addition, skill has been measured by component skill tests (Turner & Martinek, 1995).

Rink, French and Tjeerdsma (1996) noted that TGfU students performed better on tests relating to tactical knowledge compared to those who were taught with a ‘technique’ based approach. In addition, from an affective and sociological perspective, it was suggested that TGfU was found to be more enjoyable and learners were more motivated to participate in physical education classes (e.g., Griffin, Oslin & Mitchell, 1995). One long-term study by Mitchell, Griffin and Oslin (1995) found that students taught with a tactical approach were able to make better decisions during games than those taught with a technique approach in field hockey classes. However, some studies have found less support for a tactical approach as compared to a technique approach. For example, Turner and Martinek (1999) found that students taught in a tactical approach did not show significant improvement in some performance outcome measures related to tackling, dribbling and shooting in field hockey although the same students displayed better control and passing. In addition, other studies (e.g., Gabriele & Maxwell, 1995; Turner, 1996; Turner & Martinek, 1992) also reported no superiority of a tactical over a technical approach for various performance outcome measures in different games and analysis of the extant literature generally reveals little in the way of empirical evidence to support its apparent effectiveness (Strean & Bengoechea, 2003; Turner & Martinek, 1999).

Why has there been such ambiguity in the data on the effectiveness of such a popular pedagogical method in physical education? There are a number of potential reasons for these inconclusive results including problems with research design. Studies have varied according to game chosen for analysis, age of participants, length and nature of intervention, variables chosen for investigation and how these variables were measured (Rink, French & Graham, 1996).

Hopper (2002) attempted to address some of the misinterpretations of the TGfU approach by stressing the inadequacy of a dichotomous approach in focusing on either skill acquisition or tactical development. This dichotomy was based on the perceived emphasis of TGfU on students' understanding of 'why' a skill is needed before they are taught 'how' to perform a skill. The difference between a technique and tactical approach is a sequencing of what comes first.

The TGfU approach has a ‘tactic-to-skill’ emphasis in contrast to the skill-based approach which has a ‘skill-to-tactic’ emphasis. The argument proposed by Hopper (2002) was to emphasize a student-centered approach rather than a content-based approach which promoted the precedence of either technical or tactical development. According to Hopper (2002), both the skill-to-tactic and tactic-to-skill approaches can be effective if the skills and tactics taught are delivered with proper progressions and within the relevant game context to be effectively understood and used by students. Hopper (2002) concluded by arguing that the comparison of a skill-to-tactic and tactic-to-skill approach presented an unwarranted direction for future TGfU research. Instead, the focus of research should be on the teaching/ learning processes underlying the different approaches (Holt, Strean & Bengoechea, 2002; Rink, 2001).

A Search for a TGfU Theoretical Framework

Although research on TGfU has been actively pursued over the last two decades, a number of questions still exist over its relative efficacy as a pedagogical method including, (a) is the perceived need to differentiate skill development from tactical development valid in assessing the effectiveness of TGfU compared to traditional technique-based approaches?, (b) is there a theoretical framework of adequate power, for providing explanatory concepts and testable hypotheses to disambiguate expectations and predictions in empirical research related to TGfU? and (c) is TGfU suitable for individuals at all stages of learning?

Clearly, the key observation is that TGfU currently lacks a sound theoretical base for examining its relative efficacy as a pedagogical approach. Griffin, Brooker and Patton (2005) commented in their review of TGfU that its efficacy could be grounded in three possible theoretical frameworks including (a) achievement goal theory, (b) information processing, and

(c) situated learning. In particular, many physical education researchers believe that the TGfU approach is generally aligned to the theoretical orientations of cognitivism and constructivism as well as situated learning (e.g., Kirk & MacPhail, 2002). The acquisition of higher order cognitive skills through the understanding of tactics and problem solving activities present in TGfU suggest that it may be grounded in such cognitive-based theories in understanding the perceived effectiveness of TGfU. However, investigations at a micro-level, although seemingly attractive and comprehensive, may not have provided an accurate picture of how development of decision making occurs in TGfU. It seems that pedagogists have tended to focus on how TGfU can be operationalized in specific pedagogical contexts from a problem-centered approach, with few attempts to critically evaluate and adequately develop the theoretical basis of TGfU.

The provision of an empirically-supported theoretical model of learning in physical education is required to provide a testable framework for investigating the relationship between pedagogical principles of TGfU and motor learning processes, with the aim of validating methodological decision-making by pedagogists. McMorris (1998) noted that there have been few attempts to examine the relationship between research on TGfU and prominent theories of perceptual-motor learning. Thus, despite its popularity, few extensive theoretical rationales for TGfU have been forthcoming in the literature that emphasizes how goal-directed movement behavior emerges in a TGfU setting. One attempt by Turner and Martinek (1995) to provide a theoretical overview for developing tactical awareness examined the role that declarative and procedural knowledge play in TGfU. The conceptual basis of this perspective is cognitive psychology and declarative knowledge purports to provide information to learners on ‘what to do’, whereas procedural knowledge represents information on ‘how to do’ actions. Turner and Martinek (1995) viewed the development of decision making skill in TGfU from an information processing perspective, in which learners use different knowledge bases to underpin function of cognitive processes such as perception, attention and memory during the motor learning. The acquisition of procedural knowledge, facilitated by TGfU, has been found to underpin successful movement performance because it engages less conscious modes of attention and movement planning.

A theoretical model that allows TGfU to be examined at a macro-level could provide a multidisciplinary framework to capture the multitude of physical, social, cognitive and environmental factors that interact to influence the learner's ability to develop goal-directed behavior. In this vein, a situated learning perspective has been proposed as a possible description and explanation of the processes underlying the TGfU approach. Specifically, a situated perspective assumes that learning incorporates the active engagement of learners with their environment (Kirk & MacPhail, 2002; Rovegno & Kirk, 1995). Sociological aspects emphasizing the role of the environment and how learning is constructed within a 'situated' setting argues that the relationships among the various physical, social and cultural parameters in the learning context plays a crucial role in TGfU (Lave and Wenger, 1991). Light and Fawns (2003) highlighted the need to adopt an embodied approach to understand the interdependence of cognition, perception and movement skill execution within a TGfU learning context. By this they meant that the acquisition of tactical knowledge can only be achieved by actually moving within a game context which TGfU provides. For them, the separation of knowledge and movement, devoid of the influence of specific learning contexts, is unrealistic in explaining how learning occurs in a TGfU approach. Certainly, a situated learning perspective provides a valuable starting point in understanding the need to investigate learning in TGfU as context dependent and where the interactive components within the learning situation all play an important role.

One contemporary theoretical framework with great potential for explaining the efficacy of the TGfU approach, although largely ignored in the pedagogy literature, is the constraints-led framework with its basis in dynamical systems theory (see Araújo, Davids, Bennett, Button & Chapman, 2004; Handford, Davids, Bennett, & Button, 1997; Rossi, 2003; Williams, Davids & Williams, 1999). The essence of a constraints-led approach to skill acquisition, which provides the scaffold for a nonlinear perspective to pedagogy in physical education, implies that educators need to understand the nature of the interacting constraints on each individual learner and how to manipulate key task constraints to facilitate the emergence of functional movement repertoires. Evidence shows that manipulation of constraints by educators can lead to the production of successful motor patterns, decision-making behavior and intentions which guide the achievement of task goals (see Chow et al., 2006). In the remainder of this paper we show how key concepts from dynamical systems theory, pertaining to the interaction of constraints and the emergence of goal-directed behavior can provide a theoretical basis for evaluating the merits of the TGfU approach. We discuss how application of a nonlinear pedagogical framework could provide rich theoretical insights for training educators, leading to better understanding of how tasks constraints can be introduced and manipulated to enhance game awareness and movement skills using a TGfU approach.

Specifically in the remaining sections of this paper we (a) appraise key features of TGfU from a dynamical systems perspective and (b) examine how a nonlinear pedagogical framework, emanating from concepts in dynamical systems theory, may provide the basis for a model to determine how TGfU can be implemented by educators, leading to effective motor learning.

Nonlinear Pedagogy: A Constraints-Led Approach as a Theoretical Model for TGfU

The Influence of Dynamical Systems Theory

In the past decades, dynamical systems theory has provided a theoretical stimulus for understanding movement behavior, as well as the role of decision-making behavior, intentions and cognitions on motor performance (see Carson & Kelso, 2004; Davids, Williams, Button, & Court, 2001; Jirsa & Kelso, 2004). Prominent ideas from dynamical systems theory have been allied to concepts of ecological psychology (see Gibson, 1979) to understand how movements are coordinated and controlled with respect to dynamic environments like sport. Research has adopted a systems perspective and sought to characterize neurobiological systems as complex, dynamical entities, revealing how the many interacting parts of the body are coordinated and controlled during goal-directed movements (see Bernstein, 1967). It is well established that patterns emerge between parts of dynamical movement systems through processes of self-organization ubiquitous to physical and biological systems in nature (see Davids, Shuttleworth, Araújo, & Renshaw, 2003). Dynamical systems are able to exploit surrounding constraints to allow functional, self-sustaining patterns of behavior to emerge in specific contexts. Interest has focused on the transitions between different stable patterns as a consequence of the interaction between different components or constraints in a system. And, the type of order that emerges is dependent on initial conditions (existing environmental conditions) and the constraints that shape a system's behavior. For example, investigations can focus on understanding how learners acquire one movement pattern to another movement pattern based on the interaction of skill level with the equipment, instructions and feedback provided. With respect to the study of dynamical movement systems, it has been argued that the number of possible movement solutions offered by the human body that needs to be regulated by the central nervous system can vary in magnitude due to the temporary assembly of muscle complexes called coordinative structures. Coordinative structures are task-specific coordination patterns assembled for the functional purpose of achieving specific movement goals, for example catching a ball or running towards a target in space (see Williams et al., 1999).

The great flexibility with which the central nervous system organizes motor system degrees of freedom (i.e. possible movement solutions offered by parts of the body) into functional coordination patterns that emerge under constraints is an important feature of the constraints-led approach which suggests how TGfU may work (Chow et al., 2006). Particularly relevant to TGfU, the interaction of the task, performer and the environment provides the 'boundaries' for an individualized goal-directed behavior to emerge and this dynamic interaction between the constraints in the learning context is inherent in situational games in a TGfU lesson. This emergent characteristic of movement coordination suggests that the existence of a common optimal motor pattern for performing a skill is a fallacy owing to the variability often observed in human motor performance (see Brisson & Alain, 1996). Individuals can use the great abundance of movement possibilities offered by our body to vary the way in which they solve movement problems, and an optimal movement pattern for one individual may not be optimal for another in relation to a specific task goal. This idea contradicts many traditional approaches to teaching motor skills predicated on the notion of an idealized, common optimal motor pattern towards which all learners may aspire (often presented by demonstrations from an expert model). Rather, the concept of emergence under constraints emphasizes the individualized nature of movement solutions as learners attempt to satisfy the unique constraints on them (Davids et al., 2001). Although similar movement patterns can be adapted and subsequently refined for motor performance, detailed analysis of movement kinematics are revealing that the specific movement patterns employed by different individuals to achieve similar outcomes are not the same (Davids et al., 2003).

Movement variability has traditionally been viewed as dysfunctional and a reflection of ‘noise’ in the central nervous system. A constraints-led approach, however, suggests that movement variability is an intrinsic feature of skilled movement behavior as it provides the flexibility required to adapt to complex dynamic physical education environments (Williams et al., 1999). In fact, individuals find it extremely challenging to repeat a movement pattern identically across practice trials (Davids et al., 2003). Variability in movement patterns encourages exploratory behavior in learning contexts, a feature of relevance when engaging in games for understanding. The paradox between stability and variability explains why skilled individuals are capable of both persistence and change in motor output during physical education (Davids et al., 2003). This feature of human movement systems actually provides performers with the capacity to invent novel ways to solve typical motor problems and to adapt to the changing task constraints of modified games. This radically different theoretical conceptualization of movement variability fits well with pedagogical claims on the efficacy of a TGfU perspective. For example, den Duyn (1996) observed that “One of the interesting aspects of the game sense[1] approach is that incorrect technique is not necessarily seen as a ‘bad thing’ that must be immediately changed. Many athletes use unorthodox techniques that still achieve the right result (and often bamboozle their opponent).” (p. 7). However, this is not to say that coaches and physical educators allow ‘free play’ and hope that learners complete a set task/ game situation in whatever way the learners deem appropriate! The teacher must consider the constraints within the learning environment so that an appropriate response can be used by the learner to achieve the desired learning outcome planned for the session.

Constraints Framework for TGfU

From a motor control perspective, Kugler, Kelso and Turvey (1982) and Newell (1996) emphasized the role of constraints in channeling motor behavior because the stability of functional coordination patterns can be altered by constraints imposed on performers. The concept of constraints is important to the nonlinear pedagogical framework espoused for TGfU. They have been defined as the boundaries or features which shape the emergence of behavior by a movement system (e.g., learner) seeking a stable state of organization (Newell, 1986). Newell (1986) classified constraints into three distinct categories to provide a coherent framework for understanding how movement patterns emerge during task performance (See *Figure 2*). The three categories of constraints are performer, environment and task.

****Figure 2 near here****

Performer constraints.

Performer constraints refer to existing structural and functional characteristics of the individual, including height, weight, body composition (physical attributes) and connective strength of synapses in the brain, motivations, emotions, intentions and cognitions (functional characteristics). An important performer constraint is the neuroanatomical design of the muscles and joints of the human body. Learners of different ages may present intrinsic differences in development of the neuroanatomical features specific to the stage of development of their body. These differences will have implications for how pedagogists structure learning tasks and plan modified games in TGfU. As noted earlier, the skill level of learners is a crucial performer constraint that will have an impact on how relevant the TGfU approach is for the development of tactical awareness for specific learners. Such an observation is supported by data from French, Spurgeon and Nevett (1995) who examined performance differences in youth baseball related to skills, expertise and age. They noted that younger players were unable to utilize advanced tactics as they were constrained by the inability to appropriately execute the necessary movement skills. It seemed that skills and tactics constrain each other, developing in tandem. These findings are harmonious with the theoretical tenets of a constraints-led perspective as we outline later. Regardless, some proponents of TGfU, have provided a modified game to introduce tactics so that all learners can learn without being handicapped by a lack of skill (Hopper, 2002).

Environmental constraints.

Environmental constraints are often physical in nature and could include ambient light, temperature or sound. In any movement tasks, gravity is a key environmental constraint that influences how movement coordination may be adjusted. Other environmental constraints include social factors like peer groups, social and cultural expectations. Such factors are of particular relevance for young learners whereby motor performance is often strongly influenced by the presence of critical group members such as the teacher or class-mates.

Task constraints.

Task constraints are more specific to particular performance contexts than environmental constraints. Task constraints are particularly important for the TGfU approach since they include the rules of the game, the equipment used, boundary playing areas and markings, nets and goals, the number of players involved and the information sources present in specific performance contexts. Clearly, pedagogists need a mastery of the task constraints of specific sports and games, since their manipulation could lead to the channelling of certain coordination patterns and decision-making behaviors (Araújo et al., 2004). Modified games in the TGfU approach typically involve modification of task constraints to allow for appropriate progressions for tactical development. For example, instead of having a full-sided game in soccer, manipulation of rules to allow a 3 v 1 situation may be presented to encourage ball possession for the team of three players. The use of modified equipment is also widely promoted in TGfU. Shorter rackets, bigger playing balls or lighter projectiles are all possible manipulation of task constraints to make the modified game easier for learners to play. As a consequence of manipulating task constraints and making modified games ‘playable’ to all learners, it would have certainly met Bunker and Thorpe’s (1982) beliefs of developing a games appreciation outcome for TGfU.

An important task constraint relates to the available information in specific performance contexts that learners can use to coordinate actions. It has been argued that biological organisms, including humans, are surrounded by huge arrays of energy flows that can act as information sources (e.g., optical, acoustic, proprioceptive) to support movement behavior, including decision making, planning and organization, during goal-directed activity. The role of information in regulating movement was particularly emphasized by Gibson (1979) who suggested that movement generates information that, in turn, supports further movement in a cyclical process. Understanding the need to keep information and movement coupled could inform how TGfU proponents design educational environments to facilitate perceptual-motor learning and acquisition of decision-making skills in games.

Implications of the Constraints-Led Perspective for TGfU

Now that we have provided a brief synopsis of the constraints-led perspective, it is relevant to ask how this particular theoretical framework can improve our understanding of the TGfU approach. A major implication of a constraints-led perspective on motor learning suggests that a key aim of games teaching in physical education is for learners to become attuned to the relevant properties that produce unique patterns of information flows in specific environments. Since flow patterns are specific to particular environmental properties, they can act as invariant information sources to be acquired by individual performers to constrain their actions (Davids & Araújo, 2005). The use of task constraints and specifically, informational constraints in TGfU will allow learners to successfully couple their movements to critically important information sources in specific contexts. With learning, games players become better at detecting key information variables that specify movements from a myriad of non critical variables. In addition, learners can attune their movements to essential information sources available through practice, thus establishing information-movement couplings that can regulate behavior (Jacobs & Michaels, 2002). For example, in a striking and batting game like baseball where the tactical problem in a TGfU lesson could be ‘Stopping Scoring’, outfielders will need to develop effective information-movement couplings by successfully perceiving positional and timing information of ball flight and coupling with appropriate movements to make a successful catch. A good example of this idea was provided by Thorpe (2001) who illustrated how someone who is falling can still pass the basketball in a temporally-constrained situation, thus demonstrating the interconnectedness of perception and movement in such dynamic sporting contexts.

It is also important to note that the interacting nature of key constraints shapes the emergence of motor behavior in the form of actions, intentions and decisions. The presence of task constraints does not influence the emergence of a decision to act per se, but determines how the specific intentions of a performer and information-movement couplings interact to allow a functional movement pattern to emerge in a modified game context (see Araújo & Davids, in press). It seems that a rich mix of structural, task and intentional constraints interact to shape the emergence of stable, coordination modes, a finding that has strong implications for learners needing to use equipment in performance (e.g., rackets, oars, balls and bats).

In relation to understanding the development of skilled games players, the constraints-led framework based on the tenets of nonlinear pedagogy could provide further insights into how sports expertise is acquired. Possession of superior knowledge, organization of task-specific knowledge, superior recognition of patterns of play and effective perception of kinematic information are all reportedly characteristics of sports expertise (e.g., Abernethy, 1994). It is plausible that skilled games players are able to form effective information-movement couplings through effective practices that focus on presenting various task constraints that interact with performer and environmental constraints. Task specific actions that satisfy goal-directed behavior could generally be seen as qualities of effective decision making, which could help in improving understanding of game tactics in TGfU. .

Below we elucidate key implications of a constraints-led perspective for teaching decision-making behavior from a TGfU approach, using the volleyball attack sub-phase as an exemplar.

Constraints on Decision Making in TGfU

The ideas of Newell (1986) on performer, environment and task constraints provide a sound framework for examining the central principle in the approach of TGfU, i.e., to develop appropriate tactical behavior in games through manipulating of key constraints. From a constraints-led perspective, the teacher's manipulation of constraints can lead each learner to attempt to satisfy them in a lesson context, thereby guiding them towards a range of suitable action solutions to tactical problems. In this view, intentions in humans are 'embodied', that is based in real world settings and constrained by a number of factors including mind, body, social and biological contexts (Davids et al., 2001). It is important to understand that the intention of the performer is emergent, that is, the decision making takes into account initial conditions that allows the attainment of a final condition along a goal path governed by the existing environmental context. Along the goal path from initial conditions to final outcome, more and more information becomes available as the learner advances towards a specific movement goal (e.g., moving to intercept a ball). Given that information emerges to carry out the intended action, the available action paths become clearer and eventually, at the penultimate moment of achieving the goal, a final path can be uniquely defined from a number of action choices (Kugler, Shaw, Vincente & Kinsella-Shaw, 1990). From a constraints-led approach, the physical educator's manipulation of key task constraints can guide learners towards a range of highly suitable action paths, narrowing down the time needed for exploratory behavior of the learner.

In a typical TGfU lesson, constraints that need to be satisfied by each learner and which may be manipulated by the physical educator are outlined in Figure 3. Figure 3 depicts a lesson in which the physical educator can provide a tactical problem to learners with an emphasis on 'setting up to attack' in a volleyball game (i.e., net-barrier game). Learners can be challenged to 'decide' when, where and how to set up an attack in the game of volleyball. In Figure 3, it can be seen that an introductory game presents an appropriate context for learners to explore how best to make an attacking hit into the opponents' court (assuming that learners have previously learned how to ‘dig’ a ball in previous TGfU lessons). Suitable task constraints can be manipulated to provide the necessary boundaries to encourage learners to execute an attack. For example, equipment constraints can be manipulated so that only badminton nets can be used which are much lower in height than actual volleyball nets. In addition, specific instructional constraints can emphasize ‘playing the ball towards an opponent by contacting the ball above your head’, encouraging learners to ‘set’ the ball up for an attack above the head. Other constraints which allow for a bounce between hits within the same team and tossing for service provide opportunities for greater success in the situational game. The task constraints in this lesson guide the learners to search for appropriate goal-directed movements to attempt to outplay their opponents. With the appropriate task constraints in place, learners will soon realize that for an attack hit to be played across to the opponents’ court, the pass prior to the attack hit will have to be high and elevated. In turn, the learners will possibly attempt to ‘set’ the ball high, either by ‘digging’ the ball or trying a ‘volley’ set. In this sense, goal directed behavior emerges without the need to provide explicit and prescriptive instructions for executing an overhead set pass for a smash. Subsequently, skill development occurs after the question and answer session (which confirms the demonstration of the desired movement behavior and decision for setting up an attack). Task constraints can be manipulated further to provide ‘tighter’ boundaries for learners to set up an attack with the modified instructions, ‘to execute set pass prior to attack hit’. Through attempting to satisfy constraints manipulated by the physical educator, learners will gradually acquire the appropriate decision making skills to set up an attack and therefore solve the tactical problem for this particular TGfU lesson.

****Figure 3 near here****

In the TGfU approach to teaching tactics and decision making, the example on volleyball setting and smashing indicate the value of allowing decision making to emerge under interacting constraints, based on the satisfaction of task constraints which interact with environmental and performer constraints. The skill level and physical make up of the learners, together with intentionality to perform the task, may also interact with the task and environmental constraints to influence the development of decision making in TGfU. Provision of relevant information through suitable questions presented by educators, coupled with the setting up of appropriate task constraints may encourage the emergence of effective tactical awareness on the part of the learners. Wright, McMeil, Fry and Wang (2005) summarized it neatly in their study examining games teaching in teacher education: Games players need to execute the necessary movements required in the game by understanding why certain moves are appropriate. The questioning process in TGfU reinforces the 'knowing' of strategy but the goal is to embody that 'knowing' in the actions carried out during the learning process (Wright et al., 2005). And from a constraints-led perspective, the 'knowing' comes about from learners satisfying the various interacting constraints in the TGfU lesson where appropriate goal-directed movements and decisions to move emerges through the teacher's careful manipulation of key task constraints.

Constraints and Skill Learning in TGfU

Earlier we suggested that a model of motor learning was required for successful understanding and implementation of the TGfU approach in pedagogical practice. A useful model for this purpose is Newell's (1985) model of motor learning which can be used to address the question about TGfU's relevance for performers of different skill levels. Newell (1985) proposed that, early in learning, the individual is at the Coordination stage, seeking to harness available movement possibilities offered by the neuromuscular system to provide stable solutions to specific motor tasks. The successful search for a functional coordination pattern allows performance of the task to a basic level, as the learner assembles component relations between relevant parts of the body. Stability and refinement of a coordination pattern is achieved as a result of the learner exploring the coupling between varying informational constraints and different performance contexts. Performers are at the Control stage of learning when they can flexibly adapt a stable coordination pattern to imprecisely fit changing performance environments. Subsequently, expert performers reach the Skill stage when they can vary a coordination pattern in an energy-efficient manner to fit changing circumstances in dynamic environments (Davids, Button & Bennett, 2005).

The constraints-led approach, incorporating Newell's model of motor learning illustrates how a suitable progression in lessons within a TGfU curriculum could be structured to allow optimum learning opportunities for learners. One suggestion is to begin with less complex games such as target games with simple tactical concepts in the TGFU curriculum as categorized under the classification system for games (see Griffin, Mitchell & Oslin, 1997) before proceeding to more complex games like invasion games (Werner et al., 1996). The use of modified games and questioning techniques within a TGfU approach serves to encourage learners to actively seek and explore a variety of solutions to tactical problems rather than receiving information passively. The delivery of exploratory or discovery learning promotes functional variability in practice and exploration of movement dynamics which enhances the search process by increasing learner's exposure to varieties of task solutions (Newell & McDonald, 1991). In relation to Newell's model of motor learning, such exploratory practice is valuable at both the Coordination and Control stage of learning for different reasons (Davids et al., 2005).

At the Coordination stage, exploratory learning is useful for learners to assemble functional and unique coordination structures to achieve a specific task goal such as kicking a ball. At this stage of learning, simple tactical problems could be presented and the emphasis may be on acquiring some basic movement pattern of performing a skill before decision making could be taught. This is to allow learners to find success in both skill execution and decision making at this stage of learning. Specifically, learners who are at the Coordination stage of learning may require modified games that have task constraints ensuring experience of success since learners at that stage may not have the necessary skills required to play a modified game that is more similar to the adult version of the game. For example, smaller activity groups, bigger targets or projectiles could be made available so that the learners could achieve success in the modified games while attempting to solve simple tactical problems without worrying too much about the lack of necessary ‘skills’ to perform the required movement in situational games. For example, in the previous example on volleyball, bigger and softer balls can be used so that the learners have a greater likelihood to execute a volleyball set or dig pass successfully so that an attacking hit can occur in the situational game. Thus, the use of modified balls allows the learner to acquire a basic movement pattern to execute a volleyball set or dig which will be useful for learners at the Coordination stage of learning. Certainly, the appropriate manipulation of task constraints support the stand put forth by proponents of TGfU that all learners can play a game if suitable modifications to the game are made to generate meaningful play (see Mitchell, Oslin & Griffin, 2005). Subsequently, physical educators could proceed to present specific skill practices which place emphasis on the acquisition of relevant movement patterns that utilize age and skill appropriate equipment for learners. While later in learning, exploratory practice allows players to refine and adapt existing coordination patterns to enhance flexibility in coordinating actions to the events of dynamic environments.

Practice structure, particularly when individuals proceed beyond the Coordination stage into the Control stage, should emphasize keeping information and movements together so that learners can start to associate movements to key information sources (e.g., hand movements to a moving ball or movement of the 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. An example of task decomposition is when learners practice the ball toss phase of a serving action in racket sports, separately from the hitting component. Task simplification refers to the process whereby scaled-down versions of tasks are created in practice and performed by learners to simplify the process of information pick-up and coupling to movement patterns (Davids et al., 2003). The use of modified games with a preservation of the intended tactical concepts at the beginning of a TGfU lesson can be seen as another example of task simplification. For example, when learning to maintain possession in soccer, instead of passing with the feet in an introductory game, learners can be introduced to the tactical concept by participation in a passing game with the hands. This manipulation of task constraints could allow more opportunities to develop an awareness of tactical requirements in modified version of soccer, with specific task constraints maintained (e.g., goals, line markings, other players). In this sense, learners at the Control stage can focus more on the tactical aspect of the game in terms of movement off the ball or concurrent movement by teammates in the surrounding environment. Subsequently, learners can engage in additional skill practices on passing with the feet, acquiring the specific skills and information-movement couplings in the game of soccer to facilitate ball control as well as ball possession.

Moreover, the use of hands in the introductory game for maintaining possession in soccer could provide teachers with an opportunity to highlight the generality of tactical concepts employed in different types of invasion games. The provision of a variety of experiences accentuates the similarities and differences among games which is the purpose of game sampling in a TGFU setting (Griffin & Sheehy, 2004). For example, positive transfer of game performance and cognitive knowledge has been observed from badminton to pickle ball (Mitchell & Oslin, 1999).

Whereas past research on TGfU has presented mainly dichotomous views on skill learning from either a tactic to skill or skill to tactic approach (e.g., Alison & Thorpe, 1997; Rink et al., 1996; Silverman, 1997), from a constraints-led perspective, this distinction may be a false dichotomy warranting further investigation. Based on Newell's (1985) model, the key issue of delivering either skills or tactics will be resolved by adopting a student-centered approach (see also Hopper, 2002). This decision is a matter of differences in the proportion of emphasis on both approaches, which is dependent on students' stage of learning. The implication here is not to solely focus on skill development for beginners at the Coordination stage of learning but to place greater emphasis on presenting games that challenge learners to develop fundamental skills required for the specific game. Development of simple decision awareness could also be taught at the Coordination learning stage for beginners to allow them to acquire basic and yet essential understanding of game play to enable them to achieve success. At the Control stage, greater emphasis could be placed on providing variations in task constraints in modified games to optimize learners' acquisition of movement skills and game awareness through increasing interactions with the environment. Such a process in motor learning occurs by adapting basic coordination pattern to achieve more challenging and varied task goals.

Newell's (1985) motor learning model presents pedagogists with a content framework to vary emphasis of TGfU games to suit the needs of each individual learner, regardless of the stage of learning. This model of motor learning shows how a constraints-led approach can be harmonious with the student-centered perspective advocated by TGfU (e.g., Hopper, 2002). A key issue for pedagogists interested in TGfU is not whether skills teaching should precede tactics, but how an appropriate model of motor learning, can be used by teachers to adjust TGfU lessons through manipulating appropriate constraints in an individualized student-centered approach.

Constraints and Feedback in TGfU

An important aspect of pedagogical practice concerns the provision of feedback to learners. For many years motor learning theorists have been concerned with the verbal and visual delivery of augmented feedback to the learner (Newell, Broderick, Deutsch & Slifkin, 2003). Recently, Davids et al. (2005) viewed the role of augmented information as directing learner's (continually evolving) search for solutions that satisfy the constraints imposed on them. From a constraints-led perspective, current research has supported the idea of allowing discovery of learning through focusing on an image of achievement (focus on the movement effects to be achieved in a practice setting) rather than an image of the act (focus on movement dynamics or specific topological form of a movement to be acquired) (see also Vereijken & Whiting, 1990). It was argued that an emphasis on achieving effective movement outcomes in sport would allow functional coordination patterns to emerge from the interactions of the various task, performer and environmental constraints. These ideas on augmented feedback have received some support from work by Wulf and Shea (2002) who observed that an external focus that directed performer’s attention towards the movement effects, rather than to other external sources of information, yielded better learning and performance of a tennis forehand drive. They proposed that an ‘external focus of attention’ did not distract learners from the movements required but instead allowed the implicit regulation of task performance and learning.

These ideas on the use of augmented feedback from a constraints-led approach have important implications for TGfU, where the teacher is seen as a facilitator and questioning is an important aspect of the educational process for the development of tactics in learners (Griffin et al., 2003). The provision of augmented feedback through questioning after the introduction of modified games helps to direct the learners’ attention to the specific tactical knowledge required rather than to the skills needed. Infrequent presentation of augmented knowledge coupled with an external focus of attention in the skill acquisition process of TGfU can allow the learner to use discovery learning to full effect and exploit self-organization processes in the motor system during practice. In addition, the use of less prescriptive and a self-regulated feedback mechanism, which complements discovery learning, could encourage the learners to more effectively explore constraints provided in TGfU for decision making.

Nonlinear Pedagogy in TGfU: Implications for Physical Education

TGfU has been actively adopted across the globe as an effective approach to teach games skills to learners in physical education and we have argued that the constraints-led framework within a nonlinear pedagogical perspective has the necessary theoretical underpinnings to explain how and why TGfU is effective in creating appropriate learning outcomes for learners.

There is a clear need in future research to provide empirical data to validate a constraints-led framework as a sound basis for implementing TGfU. In addition, the collection and analysis of empirical data could present important implications for structuring practices and delivery of instructions as well as feedback in physical education in general.

The use of appropriate models of motor learning, such as that of Newell (1985), will assist researchers on TGfU in understanding how it can be used with learners at different skill levels. Specifically, valid categorization of learners could help researchers understand differences in expected performance outcomes for different learners within a TGfU approach more successfully. Progressions for TGfU lessons and activities in physical education may be more effectively planned, taking into account the needs of learners at different stages of learning in a student-centered approach. Greater emphasis on tactics or skills can be presented in introductory games through the manipulation of task, performer and environmental constraints without compromising the core objective of developing game awareness for learners through TGfU. For example, a teacher could present more complex games by progressively manipulating specific task, performer and environmental constraints to guide the learner to explore relevant tactical solutions. The challenge for the teacher is not just to understand how to manipulate constraints, but to identify the key individual constraints that can be presented to students to encourage learning. From a pedagogical perspective, the TGFU approach empowers the learner to become active learners (Kidman, 2001) and the manipulation of constraints within TGFU lessons encourages learners to engage in self-discovery which could lead to greater enjoyment and motivation. The debate about the need to differentiate skill development from tactical development in assessing the effectiveness of TGFU over traditional technique-based approaches may also be secondary since the primary goal is to determine and comprehend how constraints can be presented to meet individual learning objectives.

In this paper we reviewed a number of alternative explanations for the efficacy of TGfU, focusing initially on cognitive, constructivist theories based in situated learning. Later we emphasized how a constraints-led framework from a dynamical system perspective can provide a relevant framework for the implementation of TGfU, which needs to be empirically examined through an evidence-based practice approach in physical education. It was indicated how TGfU could gain an input from the motor learning and control literature to provide a much-needed explanatory theoretical framework for understanding and implementing TGfU (see McMorris, 1998). We proposed how the exploration of employing key conceptual components from a dynamical systems perspective could also lay the foundations for the development of a conceptual model for nonlinear pedagogy, providing theoretical framework to further examine motor learning issues in pedagogy and physical education. While the potential for theory development in this area is significant, there is now clearly a need for established programs of empirical research to investigate how manipulating performer, environmental and task constraints can strengthen the interaction between the intentionality of learners and the emergent movement behavior. This body of research will clarify specific practical recommendations for structuring effective learning progressions during the process of skill acquisition through TGfU and also shed valuable knowledge on structuring appropriate pedagogical interventions in our schools.

Footnotes

1. The name given to TGfU approach in Australia

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Figure Captions

Figure 1. Games for Understanding Model (Adapted from Werner et al., 1996).

Figure 2. Emergence of movement behavior from the interaction of key performer, environmental and task constraints on the learner, as modeled by Newell (1986, 1996).

Figure 3. Representative TGfU lesson plan for net-barrier (volleyball) game

Figure 1

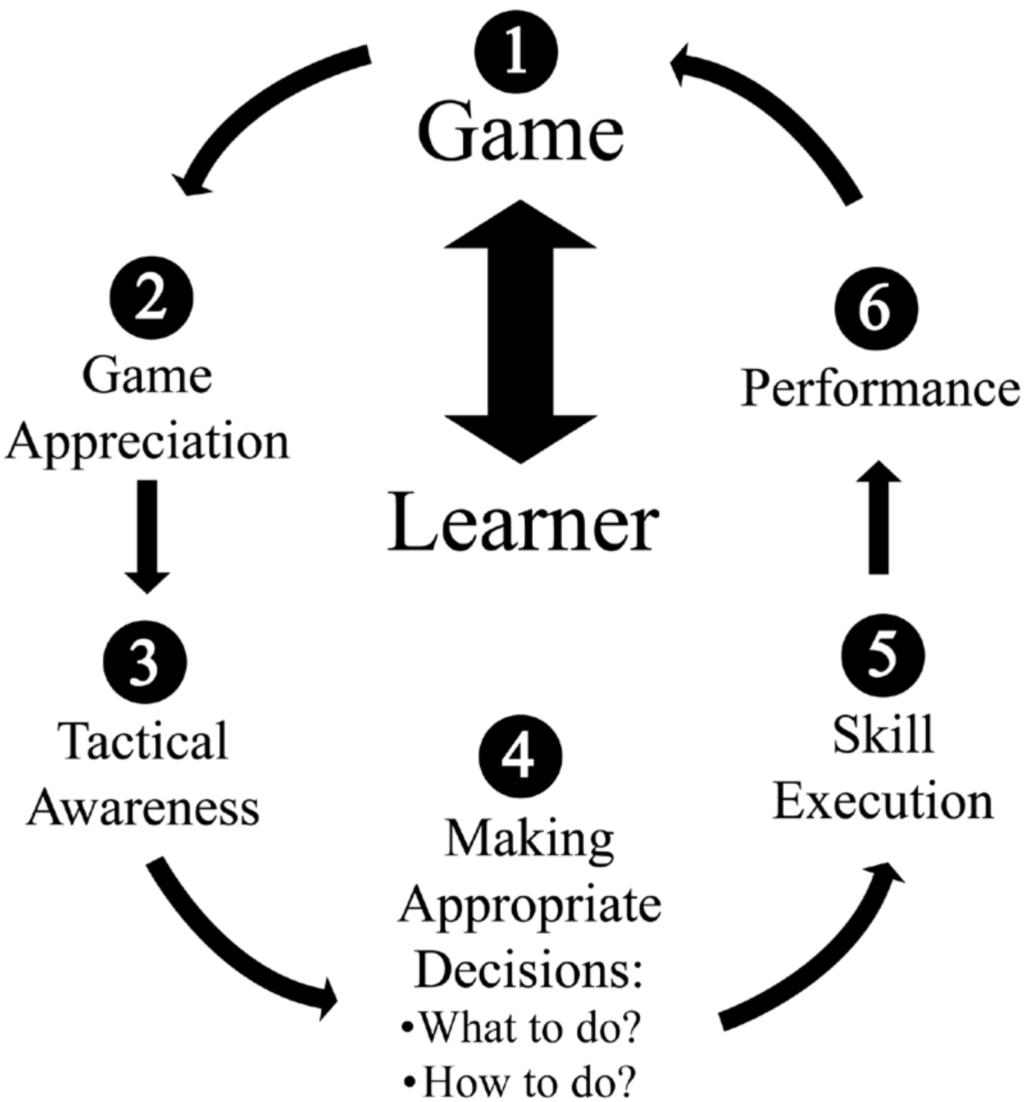

1
Game
Learner
2
Game
Appreciation
3
Tactical
Awareness
4
Making
Appropriate
Decisions:
•What to do?
•How to do?
5
Skill
Execution
6
Performance

Figure 2

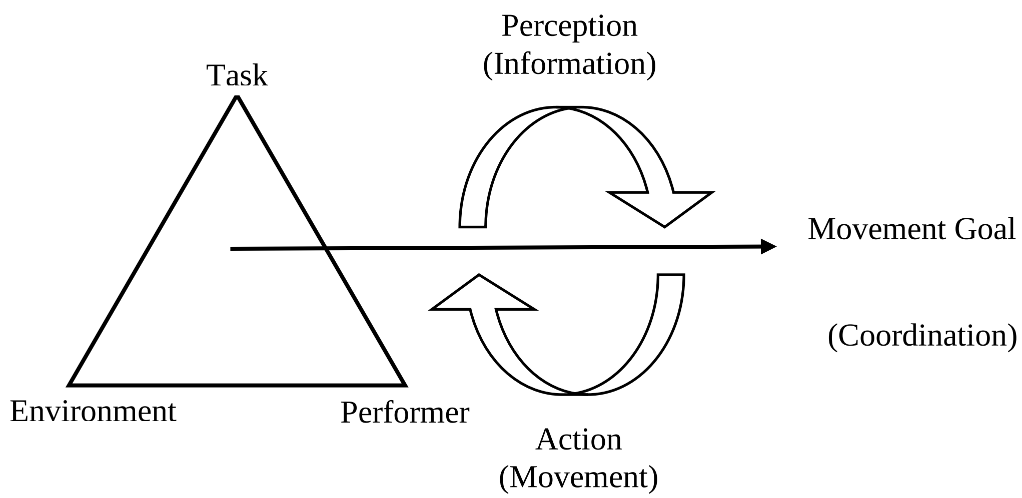

Perception
(Information)
Task
Movement Goal
(Coordination)
Environment
Performer
Action
(Movement)

Figure 3

LESSON PLAN (UNIT: Net- Volleyball)

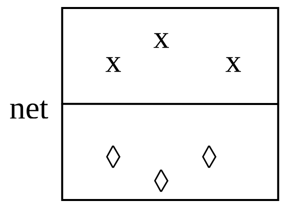
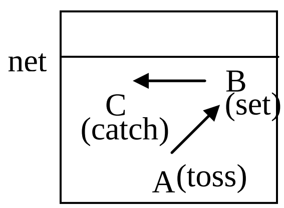
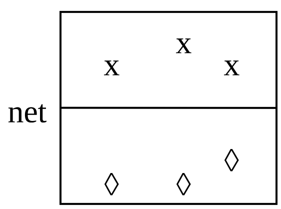
Level: 8th Grade Lesson No.: 3 Class Time/ Duration: 30 mins

Date: ________ Venue: Indoor Courts

Equipment needed: 3 sets of badminton posts and nets
16 volleyballs, markers and cones

Tactical Problem: Setting up to attack

Lesson Focus: Set up volley pass for attack hit

Situational Game 1: **Goals:** 1) Score points to win rally 2) 10 points to win set **Conditions:** 1. Bounce between passes allowed 2. No consecutive hits by the same player 3. Ball has to be hit above head when played over to opponents 4. Toss to serve 5. Maximum 3 hits per side	**Organization:** 3 v 3 in half a badminton court 	**Observation/ Evaluation:** Ball to be set high near the net	**Time:** 8mins
Question & Answer: 1) Where is it easiest to attack from? Ans: Near the net 2) How would you score a point? Ans: Execute an attack hit above the head 3) What must your team do to prepare for an attack hit? Ans: Set up to attack			**Time:** 2mins
Practice Task: Volley pass from setter to spiker **Goals:** 1) Successful pass to spiker 2) 3 good passes before rotation **Condition:** 1) Toss, set, catch 2) A to toss, B to set and C to catch the ball above head	**Organization:** 	**Teaching Points:** 1) For setting, get under the ball 2) Bend knees 3) Contact ball with finger pads, flick wrist, elbows bent and wide 4) Set the ball high 5) Face direction of pass	**Time:** 8mins
Situational Game 2: **Goal:** To execute setting up to attack effectively (as a team) **Condition:** 1. As per Situational Game 1 2. Point won only with set pass prior to attack hit	**Organization:** 	**Evaluation:**	**Time:** 10mins