A ‘Fundamental’ Myth of Movement With a ‘Functional’ Solution

By James R Rudd, Jonathan D Foulkes, Mark O’Sullivan and Carl T. Woods

1. Abstract

Over the last two centuries, there has been a belief that coaching and physical education should be informed by a blend of experiential and empirical knowledge (Bailey et al., 2018). The challenge we face, though, is that whilst these forms of knowledge coexist and entangle to inform an individual’s pedagogical practices, they operate on very different timescales. For example, stage-based models of movement skill that prioritise the acquisition of idealised, *fundamental* ‘techniques’ are still common to many national sporting policy documents. This manifests in many coaches and teachers, often having been coached themselves by such linearized approaches, to continue to draw on such experiential knowledge to instil the *fundamentals* into the youth athletes of today. Thus, the challenge is in overcoming these ‘myths of yesterday’ to progress into the ‘truths of today’. Namely, the movement science literature stage-based models were contemporary in academic texts books in the early to mid-20th century. The myths of ‘fundamentals’ is born out of mid – end of the 20th century motor learning literature, grounded on the idea that practitioners must reduce the amount of information in an environment to assist the learners’ brains in processing information. At the end of this chapter, we provide a contemporary understanding of movement learning, calling for a shift in coaching practice that moves from ‘fundamental’ to *functional*. That is, from reductionist applications to facilitating emergent functional relationships between the performer and the constraints of their environment (Renshaw & Chow, 2018).

2. Fundamental Movement Skills

Fundamental Movement (Motor) Skills are considered to be the foundational skills that enable the acquisition and development of more complex skills, often required for participation in many organised and non-organised physical activities for children and adolescents (Seefeldt, 1980). In the simplest terms, they are the foundational stones from which all movement is to be built upon. The premise is that achieving mastery of a group or set of fundamental movement skills means a performer will become both a versatile and highly skilled mover across a wide range of physical activity and performance environments. It is a widely held assumption across the sporting community that once a child or adult has 'mastered' the fundamentals of a given sport or activity, they will then be able to advance to competitive game play, where they can be taught complexities of the game, such as tactics and strategy.

Despite these long-held assumptions, the concept of fundamental movement skills has, in recent years, been critiqued for its – ironically – lack of theoretical foundation (Almond, 2014). Moreover, its ontological basis is dualistic, viewing movements as separate to or detached from the context in which they emerge, thereby neglecting the essential embodied-embedded nature of learning. To that end, the aim of this chapter is to explore the conceptual and theoretical roots of fundamental movement skills, and through doing so, begin to appreciate how traditional approaches to motor learning have tacitly reinforced traditional sport coaching pedagogical practice. The second part of this chapter will explore how the contemporary motor learning theory of ecological dynamics moves us to appreciate the *functional* nature of movement skills, leading to the reconceptualization of fundamental movement skills to *functional movement solutions*. Finally, we explore the wider ramifications of an ecological approach to how we conceptualise learning and sport coaching practice.

3. 'The Roots of The Tree': Where it originated

For much of the 20th century, the dominant theories of skill learning were stage or stepped theories of learning, and the information processing theory. Thus, we start with a brief insight into both of these theoretical constructs.

3.1. Maturational stage perspective of motor development (1925-1960s)

Movement scientist of the early 20th century believed that the development and learning of movement skills were first driven by genetics (nature), and then once a rudimentary form was developed, that further learning was driven by the environment (nurture). The maturational stage perspective categorises movement skills as being in one of two stages; either phylogenetic or orthogenetic movement patterns. Phylogenetic movement patterns, such as walking, develop without assistance as they are integral for interaction with our surroundings and essential for the survival of the human species. Orthogenetic motor skills, on the other hand, reflect socially driven motor skills which are not required in order to function in normal everyday activity and, as a result, are more affected by the practice of complex movements, for example skills such as an overarm throw or tennis serve (Magill, 2011). However, as pointed out by Wickstrom, (1977), it becomes hard to distinguish between phylogenetic and orthogenetic skills once a child has mastered walking. For example, throwing has been categorised as phylogenetic, as rudimentary form will develop without practice and instruction (e,g, Espenschade & Eckert, 1967)[1]. A possible reason for this confusion, as pointed out by Langendorfer and Roberton (2002), is that phylogenetic skills are driven by genetics and as such, a rudimentary throwing technique would be regarded as predominantly phylogenetic, while a masterful throwing pattern would be considered orthogenetic. This perspective could be applied to all movement skills, as argued by Gallahue, Ozmun, and Goodway (2012). In summary, the maturational stage perspective sets out that fundamental movement skills are driven by genetics until children possess a rudimentary motor pattern (orthogenetic) and that they will only progress to mastery (orthogenetic) with opportunity for practice, instruction and modelling (McKenzie, Alcaraz, Sallis, & Faucette, 1998).

[1] Interestingly, though, in the second edition of this text, the authors labelled such an action as an orthogenetic skill – perhaps highlighting the paradoxical nature of categorising movement in a dichotomised way.

3.2. Information processing theory (1960s-2000's)

The information processing theory moves away from a maturational world view of movement skills, towards a more cognitive-oriented theoretical explanation as to *where* and *how* children learn movement skills. Specifically, this theoretical stance moves away from the stage approach (as seen in the maturational stage perspective), as it does not view early learning as being driven by genetics, but rather by the processing power of our brains (Summers & Anson, 2009). It can be said that the information processing theory was a more useful theory for coaches and practitioners as it provides a pedagogical template for how a practitioner could support the learning of movement skills. Despite critiques of the theory, which we will go onto unpack shortly, it is still the dominant foundational theory for teaching and coaching in sport at all levels.

Information processing theory postulates that information enters an individual through the sensory system (e.g. visual, auditory, proprioceptive) and, like a computer, is encoded and stored in either short- or long-term memory, depending upon the importance of the information. The central nervous system acts as the 'hardware' whose function is to order, monitor, select and organise the information, which dictates an internalised prescription of movement, coded as symbolic knowledge structures (Anson, Elliot, and Davids, 2005). Information processing theory, thus, drives a top-down approach to movement with a construct located inside the brain, such as a schema or a mental representation (Schmidt, 1975). This representation is consolidated as a result of the learning process so that a plan of action can occur before a movement emerges. This approach holds with the premise that learning is reflective of the maturation of a mental model and is a gradual linear process (Wulf and Lewthwaite, 2016, Wulf, Shea and Lewthwaite 2010; Wolpert and Flanagan, 2010). This theory posits that children become skilled movers through consistent repetition of a skill, progressing through three observable stages of learning: cognitive, associative and autonomous, as they consolidate a mental representation. In the cognitive stage, the child is overwhelmed by a wealth of information. The child's full attention is focused on trying to understand the 'fundamentals' – in other words, the demands of the goal-directed movement and the elaboration of a plan of action (i.e., the movement response). This cognitive stage is characterised by high attentional/cognitive load, whilst execution is effortful, erratic and full of errors. In the associative stage, the child understands the ‘basics’ and tries to gradually reduce the discrepancy between the intended and the actual performance (i.e., reduce variability in the movement) by means of repeated practice, leading to a reduction in attentional demands meaning the brain has more processing power for more tactical and technical information. In the final stage of learning – the autonomous stage – the execution of the goal-directed movement or skill typically involves a minimal number of conscious thought processes, whereby accurate and coordinated movements are performed autonomously. The child is now understood as possessing a great deal of cognitive capacity to take on more challenging aspects of the game.

3.3. ‘A Well-Trodden Path’: The rise of the traditional approach to sport coaching and physical education

The traditional approach to the motor learning process has led to the belief that to teach movement skills, a qualified supervisor/teacher/coach is needed to prescribe a putative, ‘ideal’ movement pattern to speed up the learning process by reducing any deviations from these technical templates. This model of learning is still dominant and has manifested itself in sports programmes across the globe. Traditionally, it takes the guise of being structured through the division of a task into an introductory activity, followed by a skill/drill practice phase where the focus is on the rote repetition of a technique or aspects of it (see example linear lesson plan in Figure 1). In ideal conditions when children have mastered the skill, they finish with a game or performance routine.

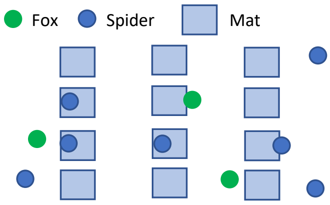
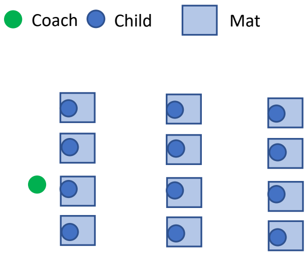
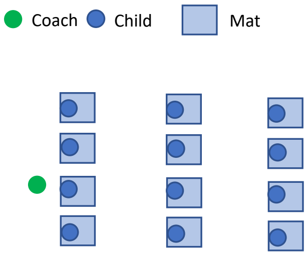
Lesson's outcome		Children will be able to demonstrate mastery in a the log roll and in rocking back and forward and will be able to use these skills in a gymnastic performance	
Linear transitions using Gentile's taxonomy		**Body:** from no body transport to body transport **Object:** from no object manipulation to object manipulation **Motion:** from environment still to environment moving **Inter-trial Variability:** from no inter-trial variability to inter-trial variability	
Activity	**Time**	**Activity Description**	**Diagram of basic set-up**
Warm up	**5min**	In this lesson children play foxes and spiders where the aim of the game is for the foxes to catch the spiders. If the spiders are caught, they freeze in to a balance position they learnt during the previous lesson. *The warm up activity is used to revisit the skills learnt in the previous lesson. Skills are practiced in a game environment (challenging end of the Gentiles Taxonomy).*	
Activity 1: Log Roll	**10min**	*Begins lesson at the bottom of Gentiles Taxonomy (progresses through taxonomy 1, 2, 3 are examples of this)* **3.** The coach explains and demonstrates the starting position of the log roll: laying down on a mat with legs straight while keeping arms straight above the head. Each child practices the starting position while the coach moves around the class giving corrective feedback. **4.** When the coach is happy that a child can master the basic shape of the log roll he/she invites the child to start practicing rolling across the mat. **5.** The coach can introduce a progression of difficulty by proposing different arms positions and different equipment for the children to practice the roll on or by asking the children to synchronise the roll with a partner.	
Activity 2: The Rock (Teaching progression for the forward roll)	**15min**	**6.** The coach explains and demonstrates the starting position: sitting down on a mat maintaining the hold of the legs pulled in tight to the chest. Children practice getting in and out of the position. **7.** The coach explains and demonstrates rocking backwards until the base the neck touches the mat and then rocking forward while keeping the body tight in the starting position. Children practice the skill until they demonstrate mastery. **8.** Children practice with a partner trying to synchronise their rocking so they stand up together. *Throughout both of these activities the coach uses challenge point framework to support learning. The*	

Figure 1.0. *Example linear gymnastics lesson plan, common practice in physical education and teacher training*

The aim of this linear pedagogy is to teach 'technical proficiency', as it emphasises a technique first orientation, wherein optimal techniques are learned 'before the introduction of rules and game play' (Blomqvist et al., 2001). The teaching and learning experience for the child includes both prescriptive actions (following technical demonstrations and instructions from the teacher/coach) and repetitive actions to try to replicate the 'optimal' technique, where variability is reduced until a performer can execute a motor skill efficiently and reliably (Schmidt, Lee, Winstein, Wulf & Zelaznik, 2018). Verbal feedback is often a one-way, 'top-down' process, with the teacher *telling* the child what they are doing incorrectly and proposing a different (and presumed to be better or 'correct') way of skill development (see Box 1.0 for pedagogical principles). From the learners' perspective, the experience can be highly prescriptive, as they receive constant instructions/corrective feedback for reproducing forms of movement or patterns of play (Davids, Araújo, Hristovski, Passos, and Chow 2012; Chen, Martin, Ennis and Sun 2008). Meaning, the coach/teacher seeks to transmit knowledge about how something 'should' be done into the minds of the child to be consolidated, stored and rolled out when the timing is 'right'. Thus, it is arguable that the rigidity and one size fits all nature of this approach leaves little room for emotionally engaged and motivated children.

Box 1.0 Four common pedagogical principles of information processing theory.

(1) There is a correct optimal movement pattern for each fundamental movement skill.

(2) Movement skills are broken down or simplified into key components of a skill for learning, as performing an optimal movement pattern is often beyond the reach of children who are in the early stage of learning a skill.

(3) Movement variability (or error) is viewed as noise in the system, which the child must reduce in their quest toward mastery of a skill.

(4) Focus of attention when performing a movement skill can be implicit or explicit and is dependent on what stage of learning a child is currently at.

3.4. 'Fitting the Jigsaw': Coaching as a compartmentalised practice

The information processing theory is ontologically dualist, as factors which may influence the development of fundamental movement skills, such as strength, flexibility, reaction time, are viewed as independent to the cognitive development of schema. Fleishman (1975), for example, stated that there are a finite set of human abilities that underlie all performances of a task. The nine motor abilities are largely physical abilities and comprise static strength, dynamic strength, explosive strength, trunk strength, dynamic flexibility, gross body equilibrium and stamina (Fleishman, 1975). Schema theory and the work by Fleishman (1975) are considered independent but complimentary to one another, in that if you can develop strength, it will likely be complimentary, but not necessarily essential for skill execution. This understanding about the relationship between abilities and perceptual motor programmes has been questioned by Esther Thelen (1989) and other dynamical system theorists (e.g. Scott Kelso, 1995). Specifically, Thelen found that an infant's walking gait is constrained by overall body mass and leg strength, with these factors directly implicating walking ability. This suggested that motor abilities are not underlying, innate or separate from perceptual skill development, but rather are entangled in the learning process.

Box 2.0 Further limitations of information processing theory.

Another major limitation of the information processing theory is the lack of clarity around the principle of changes in the hypothetical cognitive structure (trace, schema), wherein correlated changes in performance as a result of practice can only be inferred (Kelso, Case, Holroyd, Horvath, Rączaszek, Tuller, et al., 1995; Whiting & Vereijken, 1993). This is known as the 'black box' approach, where we see information go into the system and the resultant movement outcome(s), but we cannot be sure what has happened in the interim within the 'black box', failing to identify where in the brain particular skills are stored and updated. This limitation has been addressed partially by recent advancements in neural imaging technologies which have indicated that both sensory and motor areas of the brain reveal a high degree of plasticity and are capable of sending signalling to the central nervous system to undertake complex skills (Blake, Byl, & Merzenich, 2002; Mogilner et al., 1993). An additional limitation of the information processing approach is that these theories are based on highly controlled experiments and manipulation of individual variables which are not representative of the real-world setting (Vilar, Araújo, Davids, & Renshaw, 2012). There is an alternative approach to motor learning that focuses on how these underlying mechanisms interact and change during the course of learning – Ecological Dynamics (Davids, 1994).

4. ‘Toward a Different Path’: Contemporizing fundamental

Dynamical Systems Theory and Ecological Psychology (1990-Present)

Dynamical systems theory moves the premise of fundamental movement skills to *functional movement solutions*. This is because it views human movement as a highly intricate network of co-dependent sub-systems (e.g. respiratory, circulatory, nervous, and perceptual) that are comprised of a large number of interacting complex components (e.g. blood cells, oxygen molecules, bone) (Button et al., 2020). The dynamical systems approach deemphasizes the top-down approach skill learning (Ribeiro et al., 2019). This means that motor learning becomes a continual process of shifting the balance between ecological information (omnipresent within our environment) and intrinsic dynamics of the individual (e.g. the capacity that exists at the time a new task is to be learned), as the system becomes attracted towards an emergent, stable pattern (Kugler and Turvey 1987).

Ecological psychology postulates a constant, cyclical use of information to regulate an animal’s behaviour (Gibson 1979). For example, as human animals move about their econiches (e.g., playscapes, schoolyards, football pitches, basketball courts, aquatic environments), they detect structure in ‘information’ (visual, acoustic, haptic and proprioceptive) specifying different surfaces, objects, mediums and events that invite or repel action (Gibson, 1966; 1979). The detection of this information (specifically, its structure by way of surface contour, texture and colour) is an exploratory process grown through *direct* engagement and interaction (Gibson, 1979).

Coupled, dynamic systems theory and ecological psychology help us explain self-organised behaviour, common to all physical and neurobiological systems. It is the passage from one organised state of the system to another (Kelso et al., 1995). Observed changes in movement skill behaviour, in this respect, are a function of the system itself (self-organisation), with no prior authority controlling or prescribing the behaviour. Once the learning has taken place, this becomes an attractor state, a stable state for the overall dynamic system. Learning does not just stabilise the control and coordination of movements, but changes the whole system – promoting a constant, *functional* shift between stability and flexibility (Kelso et al., 1995).

4.1. Toward *Functional* Movement Solutions

To support how sport scientists, coaches and teachers utilise these theories in practice, they have been operationalised under the umbrella of ecological dynamics. Ecological dynamics approach views movement as emerging from a self-organising relationship formed between an individual, the task being performed, and the environment in which it occurs (Davids, Handford, and Williams 1994; Warren 2006). Intentional actions are understood as dynamic functional movement solutions that emerge as each learner continuously interacts with an array of constraints related to the task and environment (Davids et al., 1994; Seifert et al. 2018; Button et al., 2020). Through an ecological dynamics conceptualisation of how movement emerges there is a necessity to reconceptualise fundamental movement skills as functional movement solutions. Functional movement solutions refer to the repertoire (cognition, perception and actions) of behaviours which allow an individual to navigate the environment, interact with others and negotiate tasks to achieve intended goals (Chow et al., 2020). For example, as children interact with their surroundings, new functional movement solutions will emerge, with these solutions revealing new information and with it, opportunities for action, referred to as *affordances* (Gibson, 1979) (see Box 3.0). This is a continuous cyclical process of exploration and revelation.

Box 3.0 What are affordances?

"The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. The verb to afford is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment."

Gibson (1979)

In other words, affordances are properties of an animal-environment system, scaled to action capabilities (e.g., speed, strength), and body dimensions (height, weight) (Davids, Araújo, Vilar, Renshaw, & Pinder, 2013) that provide different opportunities or invitations for (inter)actions (Rietveld & Kiverstein, 2014; Withagen et al., 2012). Indeed, humans perceive the environment in relation to its functionality, and its meaningfulness detected in affordances, which provides insights into what they learn and how they decide to act (O’Sullivan et al., 2020; Reed, 1996).

A child who has the opportunity to explore many rich and varied movement environments will experience continual synergy (re)formation, leading to a greater breadth of stable coordination patterns (known as *attractors* in dynamical systems theory) to support movement functionality (Hanford et al 1997). The re-shaped repertoire of coordinated movement patterns that emerges through learning and development will increase the likelihood that the child will become proficient and confident in their own ability to function, and perform successfully, across multiple sporting and physical activity environments (Rudd et al 2021). By embracing the term functional movement solution as practitioners, we open ourselves up to a constraints-led approach to the acquisition of movement skills (Renshaw & Chow 2019).

4.2. ‘Simple Rules; Complex Patterns’: The Constraints-Led Approach to coaching and teaching

The Constraints-Led Approach (CLA) is an important coaching methodology built upon the foundations of dynamical systems theory and ecological psychology. Using this methodology, coaches can support performers in adapting their movements to the tasks and environments in which they are performing (Davids et al., 1994; Handford et al., 1997; Davids et al., 2008; Button et al., 2020). It is based on Newell's (1986) model of interacting constraints, which he defined as boundaries that shape the coordination and control of an animal's behaviour, from a practical perspective, two important points from Newell's (1986) model of interacting constraints are worth briefly highlighting: (i) practice is a *search* for task solutions; and (ii), the main goal of a performer is to satisfy the immediate constraints acting on them. The key here is that constraints do not cause behavior, but continually perturb it (Davids, Hanford & Williams, 1994). As the performer moves through an environment the continual coupling between perception and action leads to self-organization of our internal biological systems (cardiovascular system, muscular system nervous system etc.) to satisfy impinging constraints this is key to the functionality of an individual, with functionality implying the ability to find functional solutions in a particular performance environment (Rudd et al., 2020, Woods et al., 2020). This is why this approach calls for a shift in perspectives, from 'fundamental' to 'functional' (O'Sullivan et al., 2020, Rudd et al 2020). Given constraints do not cause behaviour but perturb it, they concurrently reduce the number of configurations available to a complex, dynamical system at any instance (Juarrero, 2000). There are many classes of constraints which can shape the behaviours of a complex dynamical system and it has been well documented that Newell (1986) considered *organismic*, *task* and *environmental* constraints to be the most influential (see Figure 2.0). Organismic constraints refer to the characteristics of each individual, such as genes, height, weight, muscle-fat ratio, cognitions and emotions. These constraints need to be considered carefully by teachers and coaches since such organismic constraints vary between, and within, each individual over different timescales. They can be influenced by factors operating over timescales of learning (hours, days, weeks) and maturation, ageing and development (months and years). Environmental constraints are more global, and can consist of physical variables in nature, such as ambient light, temperature and altitude, or social features such as historical, cultural and societal values, beliefs and customs. Task constraints are more specific to performance contexts than environmental constraints and include task goals, specific rules associated with an activity, use of activity-related implements or tools and particular surfaces or objects involved in performance (Davids et al., 2008). A broad range of varied movement and play experiences, not only during childhood and youth, but also into adulthood, can help an individual maintain and enhance physical activity to support their skilled adaptation to the environment (Button et al., 2020; Chow et al., 2020).

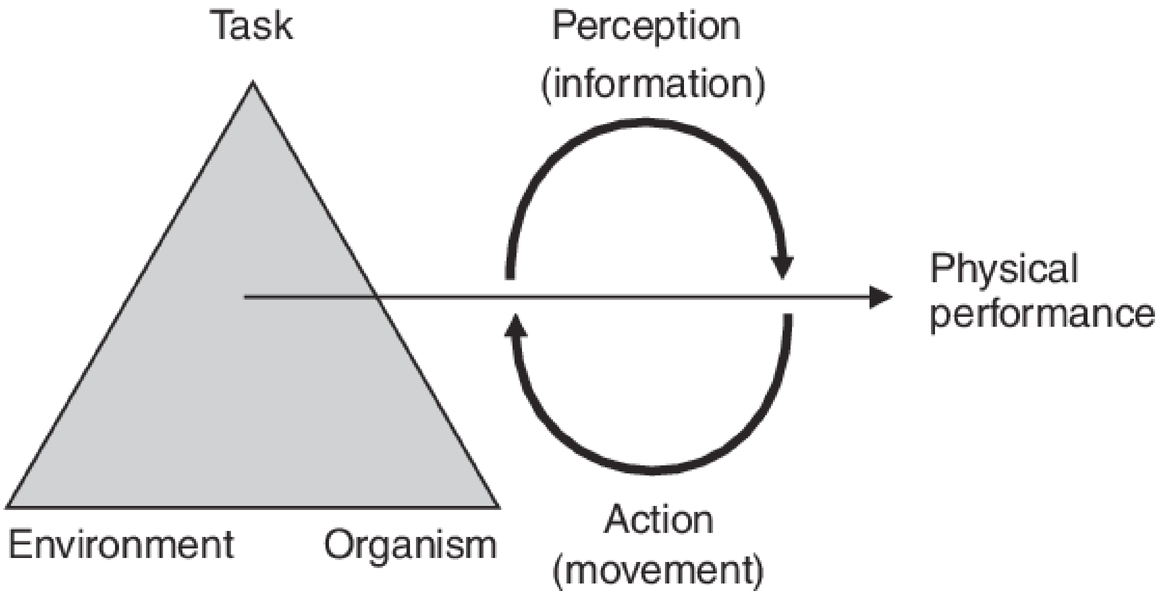


Figure 2.0. *Newell's model of interacting constraints, illustrating the cyclical process of perception and action.*

Fundamentally, a CLA highlights the non-linear interactions between performer (individual), task, and environment (Handford et al., 1997; Davids et al., 2008). In the CLA, more skilful performance emerges through self-organisation under constraints as individuals become perceptually attuned to the key information sources which can regulate their actions in specific performance environments (when performing or learning) (Chow, 2013). A distinguishing feature of the CLA is that its practice design and delivery is informed by the principles of a Nonlinear Pedagogy (see Box 4.0 and Figure 3.0 in addition to Rudd et al., 2020a, 2020b).

Box 4.0 Principles of nonlinear pedagogy.

(1) *A Representative learning design* highlights the importance of skill transfer between multiple settings. Informational constraints sampled from competition (i.e., opponents, ground surfaces, time of day) are carefully designed in to practice tasks to support learning transfer.

(2) *Movement-perception coupling* must be maintained when performing skills. This means that skills are practiced in their entirety rather than broken down into component parts or in decontextualized fashion.

(3) *An external focus of attention* allows for self-organization of movement patterns to meet the goal of the task

(4) *The manipulation of constraints* – through careful manipulation of task constraints will lead to self-organisation and the emergence of a new functional movement pattern.

(5) *Infusing perturbations within the learning process*. This means that we see variability as exploration of the taskscape and not as error in the system as would be the case with traditional pedagogies. This means as long as the skill is functional and achieves the intended outcome then it is to be accepted as a solution.

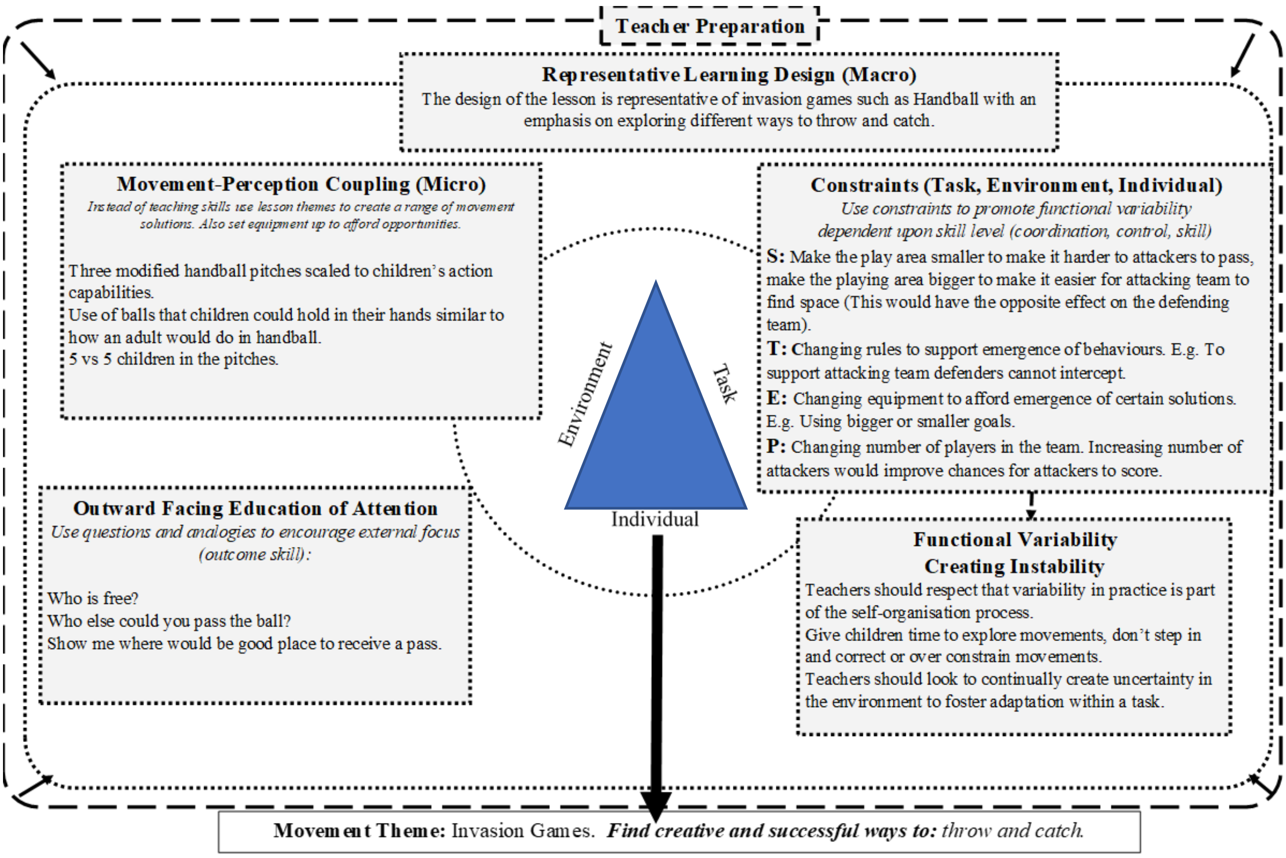


Figure 3.0: SAMPLE-PE research project example: Non linear invasion games lesson plan for young children

4.3. Manipulation of Task constraints to support the emergence of functional movement solutions

Manipulating task constraints can be a powerful pedagogical tool to support the exploratory activity of learners at all levels of skill and experience. A key and often overwhelming challenge for inexperienced practitioners is identifying which task constraints to be manipulated to encourage an individual to explore their environment – developing their functional movement skills. The STEP framework (Youth Sport Trust, 2018) suggests how parents, teachers and coaches could facilitate learning by attending to four major task constraints: Space, Task, Equipment and People. Manipulating one or more of these constraints can help to influence learners' intentions to explore different affordances in a performance environment. For example, learning can be encouraged by changing the equipment in a learning task and the number of people taking part in an activity or game. Manipulating these task constraints could lead learners to explore an abundance of affordances (opportunities for action). Let us consider a child who tends to repeat the same movement solution, whilst being challenged by the teacher to explore different ways of negotiating a particular play space. The child could be moved out of their comfort zone and challenged to adapt their actions, not by directions in the form of specific, prescriptive instructions, but rather by teachers introducing very simple rule changes to change intentions and guide exploration, for an example see Box 5.0.

Box 5.0 Example of a coach manipulating task constraints**.**

A soccer coach observing a small sided game might want to educate players attention to the possibilities of exploiting gaps and space (by dribbling, passing or shooting) just after they have won back possession. The coach may add a task constraint such as if a team intercepts a pass and scores a goal, then that goal counts as double. This task constraint places a risk on passing but does not exclude its utility. When in possession, this risk could invite players both with and without the ball to self-organize

their individual and collective behaviours to support the player in possession. While the targeted intention with the task constraint is to shine a light on opportunities to exploit opponent's defensive disorganisation just as they lose possession, it also invites opportunities for teammates and opponents to continuously adapt their positions to local information (e.g. player in possession, and positioning of nearest opponents).

5. Conclusion

The aim of this chapter was to explore the conceptual and theoretical roots of fundamental movement skills, starting from the maturational stage perspective and its subsequent effects on pedagogical practices in sports coaching. In contrast, it is hoped that the contemporary learning theories around ecological dynamics highlighted in the second part of this chapter have emphasised the progress that has been made in this field in recent years. In particular, it is hoped that the shift towards the idea of movement skills now being seen as *functional movement solutions* restores the balance between the performer and their environment when seeking to explain and understood movement skill. We encourage coaches at all levels to explore the contemporary ideas introduced in this chapter, broadening their experiential knowledge guided by contemporary empirical insights.

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