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CURRENT OPINION

Talent Development in Sport Requires Athlete Enrichment: Contemporary Insights from a Nonlinear Pedagogy and the Athletic Skills Model

João Ribeiro[1] · Keith Davids[2] · Pedro Silva[1] · Patrícia Coutinho[1] · Daniel Barreira[1] · Júlio Garganta[1]

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Abstract

Traditional talent identification and development programs have sought to identify and select the most promising children as athletes of the future, to provide them with specialised training and preparation for expert performance in sport from an early age. Traditional models of talent identification and development tend to be linear, emphasising the numbers of hours spent in specialised training. However, major concerns have been raised by evidence emerging on psycho-emotional and physical issues with early specialisation programmes, and negative associations with wellbeing and mental health. More contemporary models of talent development emphasise a deep integration of specialised training with more general enrichment of athleticism. This integrative process enhances self-regulation processes of perception and action, as well as emotional control and social interactions, all of which underpin sports performance at elite and sub-elite levels. Here, we discuss insights and principles of contemporary models of pedagogy, such as Nonlinear Pedagogy (NLP) and the Athletic Skills Model (ASM), which offer valuable frameworks for talent development. We conclude by considering implications of adopting such principles for developing athlete functionality in specific performance environments.

Key Points

Traditional talent identification and models are based on a linear model of the learner and the learning process and lead to early specialisation in children as young as 5 years of age.

Nonlinear Pedagogy and the Athletic Skills Model comprise contemporary models that provide a nonlinear perspective on talent development, precluding identification and selection of children as athletes with potential specialisations at younger ages, indicating when specificity of practice is important and when general preparatory experiences are important for developing foundational movement capacities.

Nonlinear Pedagogy and the Athletic Skills Model focus on the development of general athleticism and require early work on physical literacy and functional movement skills, followed by later specialised training development and performance preparation programmes.

✉ João Ribeiro
joaoribeiro@fade.up.pt

1 CIFI2D, Centre of Research, Education, Innovation and Intervention in Sport, Faculdade de Desporto, Universidade Do Porto, Rua Dr. Plácido Costa, 91, 4200-450 Porto, Portugal

2 Sport & Human Performance Research Group, Sheffield Hallam University, Broomgrove Teaching Block, Broomgrove Road, Sheffield S10 2LX, UK

1 Introduction

Sports organisations around the world have implemented talent identification (TI) and talent development (TD) programs seeking to identify and foster the next generation of elite athletes. Traditionally, TI programs are conceived to identify talented athletes in childhood (although talent can also be identified during adulthood) who putatively display superior performance in sport-specific skills that can be predictive of future career success at a senior level [1]. These ideas are not just idealistic, philosophical stances, but are reflected in overt political and economic decisions made at the highest levels of governments and elite sports organisations. A driver for early specialisation models of talent identification and development has been the deliberate practice approach (for an overview see [2]). This approach to expertise emphasises that highest levels of performance cannot be attained without undertaking an average of 10,000 h of intense, not inherently enjoyable, specialised training in one specific domain [3].

Several physical, social and psych-emotional long-term negative consequences have been associated with the early specialisation approach (see, for example, [4]). Little conclusive evidence supports the effectiveness of traditional TI approaches, which are entirely predicated on the principle of specificity of training and practice. There is compelling evidence that children are treated as 'mini-adults' in such programmes, rather than engaging in childhood play and practice activities, both structured and unstructured [5]. Instead, children are being exposed to intensive, repetitive training drills during early development, which increases the risk of specific types of over-use injuries, decreased sport enjoyment, increasing burnout and dropout rates and stifled psychosocial development. Another major issue is that many linear TI programs tend to display an 'organismic asymmetry' [6], biased in early identification and selection towards an individual's *physical* properties (e.g. height, weight, strength, power, speed assessed on performance in standardised tests) recorded in a snapshot at one moment in time [7]. A major issue underlying traditional linear models is that they are dominated by specificity principles and early specialisation experiences in a child's development.

This inherent bias towards specificity and early specialisation experiences clearly plays down the contributory role of other more general play and practice experiences and their influence on motivation, self-regulation, propensity to learn and cognitive engagement, and emotional control. To counteract this organismic asymmetry, a comprehensive theoretical rationale has been proposed to provide a holistic, integrated view of a developing athlete as a complex, dynamical system [6]. Integrating key ideas from ecological dynamics and dynamical systems theory may serve as a valuable theoretical template for modelling and understanding expertise and talent in sports performance. The enrichment of general capacities and abilities during childhood, adolescence, and even into adulthood, can enhance physical literacy across the lifespan to underpin specialised training at the right time [8]. In this Current Opinion, we briefly overview current issues of traditional TI programmes, before proposing a novel way of viewing talent based on two levels: the development and adaptation of functional, general and specific abilities and skills throughout each individual's lifespan.

2 Current Issues with Traditional Talent Identification and Development Models in Sport Systems

A particularly important issue is that inherent linearity of traditional TI and TD models neglects criteria used to evaluate the potential of a child to become a *future* skilled, adult athlete, which is often confused with *current* performance levels of a young person [9]. The timescales of development and performance preparation are interlinked but different. A key question is: how can we predict *future* potential in an individual as a nonlinear dynamical system, based on performance characteristics (e.g. physical/physiological, technical, tactical, psychological, emotional and social) that may or may not change radically across time through maturation, development, practice, learning and experience, as well as being influenced by genes? A major concern of early identification systems is that athletes are selected according to observations of early performance measures without considering changes that may emerge during developmental stages of later childhood, adolescence, and early adulthood. Current performance values need to be considered as *tendencies*: no more than estimates, which may or not be eventually aligned with potential achieved. Indeed, correlations between junior and senior success in competitive sport achievements and performance outcomes are weak [10]. From an ecological dynamics perspective, of fundamental importance is what happens during enrichment experiences, non-specialised and specialised, in play and practice early in an individual athlete's development that can support specialisation at the right time for each individual.

2.1 What Does Athlete Enrichment Mean?

Enrichment in athletic development refers to the rich variety of play, physical activities, games, and sports, that children and youth experience prior to (as well as during) the specialisation phase in talent pathways [11, 12]. Enrichment activities are numerous and can engage perceptual, cognitive, psychological, emotional, and physical subsystems in performance. Exposure to an extensive range of sport experiences can help a child gain vital foundational movement skills needed later in the demanding specialisation phase in athlete development programmes. Therefore, athlete enrichment is critical to specialisation in sport, especially prior to, but also during, dedicated training in a target sport. Enrichment starts in early physical education through the development of physical literacy to enable foundational movement behaviours and a love of moving [8, 13–16]. An important aspect of enrichment through early motor-learning experiences is skill adaptation through exposure to unstructured play and exploratory practice in more structured programmes [12–18].

Enrichment processes involve a subtle blend between specificity and generality of practice to provide each athlete with a distinctive skill set, adopting an 'athlete-centred' approach to talent development, which is completely aligned with a nonlinear perspective of human behaviour [10–12]. The aim is to enhance the self-regulating performance of each athlete, decreasing coach-dependency over time and focusing on an integrated mix of skills for cognitive and emotional control, perceptual awareness and a repertoire of actions to solve problems and face competitive challenges (for examples of self-regulation in swimming see [14], and throughout the rounds of a long jumping competition, see [19]). Enrichment continues during childhood and youth phases where the challenge is to integrate broader physical activities with more specialised training experiences (the latter could be viewed as a form of dedicated enrichment in specific performance environments). While specialised training is important and necessary at the right time for an individual athlete, *early specialisation* programmes can inhibit the innovation, creativity, curiosity and exploratory behaviours required of young children because they do not expose them to a diversity of affordances or opportunities for action when needed (i.e. during the early stages of sport and motor development).

Motor learning theory has provided a body of research on the importance of specificity of practice and learning in sport [20], although there has been less attention, especially in recent decades, on effects of general learning experiences and activities and effects on expertise. Ecological dynamics has clarified that the relationship between specificity and generality of practice concerns an issue of *timing*, signifying that both have a role to play in athlete development, with the emphasis on each type of practice changing with development stages [10–12]. Sport scientists and coaches need to consider effects of specific and general practice at *different* times in an individual athlete's developmental pathway, attending to the nonlinearity of the constantly changing sub-systems underlying performance (e.g. psychological, emotional, cognitive, perceptual and physical), due to learning, experience, maturation and development [10–12]. Next, we consider how practice designs can be differentiated depending on the needs of each athlete on the pathway.

3 Enrichment of Athletic Talent in Sport Through Integrating Generality and Specificity of Practice

Previous research has revealed that the principle of specificity is highly important from the perspective of practice and training for skill acquisition and physiological conditioning. It has taken longer to clarify that generality of practice, concerning enrichment of underpinning skills, capacities and abilities, is also important to develop athleticism. Over the decades, two important aspects of practice and training designs (specificity and generality of sport practice experiences) have tended to be juxtapositioned against each other in a false scientific dualism [20]. The main issues debated included the role of general motor abilities in underlying a learner's development in one context and transfer of practice task design (do learning experiences need to be specific or can one's performance potential in a target sport be predicted from performance in a different, related sport or activity?).

In contrast to the specificity of skill learning, research sought to highlight the importance of an underlying motor ability, which is more or less general, more or less inherent, supporting the identification and selection of individuals to learn specialised motor skills easily and to become proficient in a target domain [20]. This idea was not supported by research which showed that to become proficient at a specific sport domain (e.g. ice climbing), one has to be exposed to specific learning experiences in climbing on frozen surfaces, such as glacial waterfalls [20]. The 'debate' on *specificity vs. generality* of abilities was resolved in favour of specificity, and the potential contribution of *generality* of motor learning play and practice experiences, which underpin athlete enrichment, may have been downplayed as a result. The key issue concerning the *complementary relations* between specificity and generality of learning experiences in play and practice gained less attention in research: when do learners need to be exposed to general movement experiences to develop their underlying athleticism and functional abilities in perception, movement and cognition, and when do they need to specialise in training with highly specific experiences? This relevant issue will be discussed in the next sections.

4 Reframing Ideas on Specificity and Generality of Practice Designs, Training Transfer and Talent Development: An Ecological Dynamics Rationale

Previous studies (see, e.g. [21–25]), have contrasted experimental data from non-specific and specific training. For example, the article by Memmert & Roth [21], examined the efficacy of various training approaches in team ball sports. Results showed that groups provided with non-specific training improved in general creativity, whilst specific training groups improved in the game-oriented creativity in which they were trained. Another study by Memmert et al. [22] examined the role of practice conditions in the development of creative behaviours in team ball sports. They analysed self-reported data from athletes on the quantity and type of sport-specific and other related practice activities experienced throughout their careers. Results indicated that more creative players accumulated more time in training for their main sport than their less creative counterparts. Findings suggested that practice experiences and early play are important influences on the development of sport creativity. These studies provided relevant, empirical tests and associated statistical analyses of specific and non-specific practice experiences in sport. What is still needed are compelling theoretical explanations *why* a better balance between specialised and general training is important for developing athletes.

Contemporary models of practice, such as NLP and the ASM (e.g. see [26–31]) have provided such a conceptualisation, enhancing understanding of the complementary relations between specificity and generality of practice experiences in motor learning. In more specific practice designs, a close relationship is developed with the rich range of varied information sources and affordances present in a competitive performance environment [19]. Representative learning designs enhance the quality of skill acquisition experiences and preparation for performance by facilitating a close match with information for action regulation and affordances to utilise for intended task goals [11, 12, 32].

Highly specific learning experiences are valuable for matching representative task dynamics with an individual's intrinsic system dynamics (i.e. genes, dispositional tendencies, capacities, propensities, and abilities) to enhance skill acquisition (see [33] for a coordination dynamics explanation). An individual's intrinsic dynamics (i.e. spontaneous coordination tendencies) are continually modified and adapted by learning, experience and practice to underpin self-regulation in sport performance, supporting physical, perceptual-cognitive and psychological, emotional and social interactions emerging during competitive performance [10]. Intrinsic dynamics support athlete effectivities, i.e. capacities for utilising affordances (opportunities for action) available in specific performance settings [6]. In ecological dynamics, an individual's effectivities can be continually enriched and developed by general sport and play experiences in throughout the lifespan, shaping an individual's skill adaptation: the propensity to use an extensive range of affordances in uncertain performance landscapes (Fig. 1).

Thus, practice is a process of searching for increasing functionality in unpredictable performance environments and increasing functionality in a specific performance environment characterises talent [6, 34–36]. This rationale is exemplified by Nikolai Bernstein's [37], p134) advocacy of practice designs to facilitate 'repetition without repetition' (see Fig. 2). Therefore, broadening the search of a performance landscape of an athlete when they are already on the talent development pathway is significant, and typically builds throughout the lifespan of an individual. Indeed, early experiences set up the athlete for further exploration, refinement, adaptation, and development of skills throughout life. High levels of athlete functionality emerge when an individual becomes skilled in interacting with concurrent and multiple affordances during practice and competition [38].

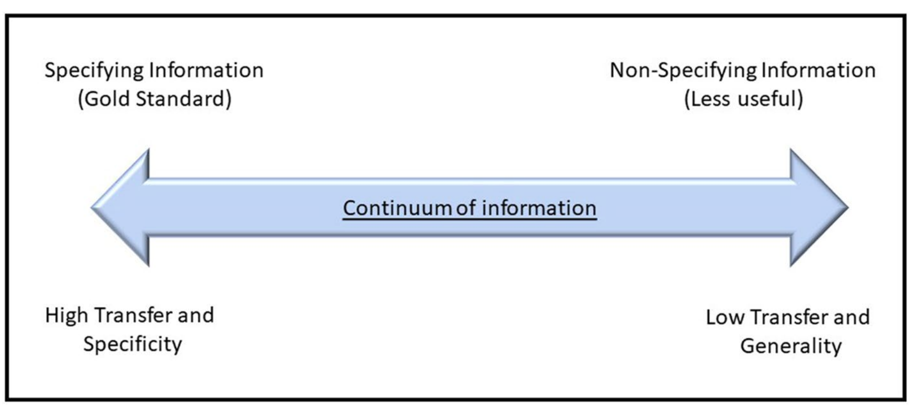

Fig. 1 Specifying and non-specifying information in ecological psychology differentiates specificity and generality of practice designs

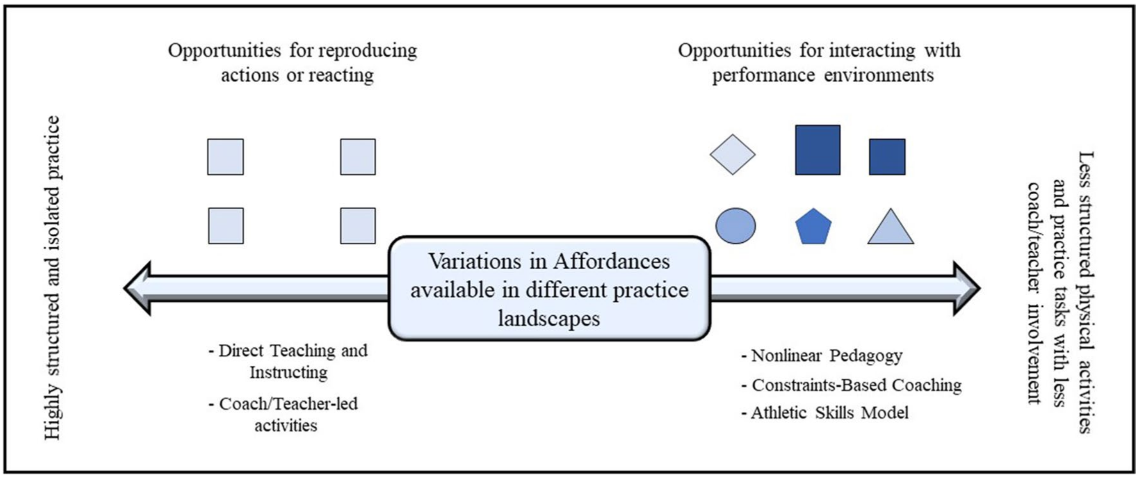

Fig. 2 A continuum of practice designs with different affordances available for learners. Learners are typically directed to fewer, similar affordances in specified areas of the learning landscape by coaches and instructors (symbolised by the uniform shapes, few in number) during highly structured and isolated practices. A more diverse and vast range of affordances can be found at the more varied and less structured end of the landscape for practice designs (symbolised by the rich and varied shapes and sizes available)

The richer and more varied the learning experiences of learners early in the pathway, the better the athletic foundation for specialised training at a later stage. To enrich athlete functionality coaches needed to create practice environments that preserve a rich landscape of affordances that provide opportunities for perceiving and acting on information, and shaping intentionality in competition [10, 39].

Through skilled intentionality (responsiveness to a field of affordances) athletes can display a tendency towards an optimal grip of affordances (the tendency of a skilled athlete to improve his/her capacity to respond to solicitations from the environment) [40]. According to Rothwell et al. [41], targeting an optimal grip is inherently related to self-regulation tendencies and the functionality of human behaviours in performance environments. Although the capacity to operate at the highest performance levels may be domain-specific, the self-regulating nature of athlete functioning is profoundly sustained by non-domain specific capacities and evolving dispositional tendencies which can be psychosocial, physical and emotional [6]. A key challenge is to identify athletes with possible dispositional tendencies (greater or less talent potential-based on a long-term monitoring of key indicators (physical, technical, tactical, psychological, emotional, etc.) that can be informative of potential future success) to operate effectively in specific performance contexts over the macro-timescales of years and decades [6]. In addition, according to the dispositional tendencies displayed by a successful athlete, one might consider looking at different *configurations of talent* (i.e. abilities, effectivities that differ among talented athletes).

4.1 The Athletic Skills Model for Developing Talented Athletes

Principles of NLP are aligned with those of the ASM (see, [27], for a detailed explanation of principles of ASM), a practitioner-developed pedagogical approach that provides an alternative framework to traditional talent development models. The ASM is a practical and scientifically based talent development model for elite and non-elite athlete development at all ages. The model is an outcome from the combined theoretical ideas of ecological dynamics, key scientific findings, and experiential knowledge from extensive practice in high performance sport (see [27]). The ASM is based on ideas from other established models such as talent model of Bloom [42], the diversification ideas of Côté et al. [43–45], and the different pedagogic aims of Balyi and Hamilton [46]. Importantly, the ASM focuses on two levels of practice design in talent development pathways in sport programmes: both general and specific. A key issue concern *when* to emphasise general motor-learning experiences and *when* to undertake specialised training steeped in specificity of practice. Both NLP and ASM advocate a learner-centred approach with an individual showing potential talent for high-level sport performance required to become a good athlete first. The initial phase of the ASM involves enrichment training of foundational movement skills, including perceptual and cognitive skills required to solve problems, make decisions, perceive information to regulate performance and emotionally engage with challenges of a competitive performance environment. In the first phase, children could be encouraged to participate in multiple different sports to acquire relevant perceptual, cognitive and movement competencies which can provide a powerful basis for later specialisation. There should also be opportunities to engage in *donor sport* activity, which share affordance fields with related sports. *Donor sports* include complementary sport activities that promote transfer of varied and specific movement experiences across a range of non-specific and specific practice environments, supporting performance functionality at the specific moment of specialisation. Abilities deemed critical to athlete development can be "donated" by performance and experience in selected sports that share adjacent fields of an affordance landscape including an extensive range of opportunities for action that can support skills transfer from a donor sport to a target sport. For example, futsal has been proposed as donor sport for learners with potential to develop ball manipulation skills for use in tight spaces of football fields [47] and opportunities for developing awareness through visual exploratory behaviours like scanning. It has been observed that, without the ball, futsal players scanned around them up to three times more often than football players [48].

Taken together, scientific theory and pedagogical evidence suggests that multisport and donor sports experiences can act as a bridge to a career in specific sports or groupings of sports. It is important to note that experience in a specific target sport at an early stage of development may be useful, of course. However, specific training and performance experiences in a target sport are not deterministic in labelling a child as only a specialist performer in a single sport. Building on high quality play and practice experiences in the initial phase, later training involves more opportunities to specialise in one sport after being identified with *athletic potential* and selected to be part of a specific sport programme, e.g. football, swimming, diving, and rowing. It is important to note that, less extensive affordance landscapes in more specialised training tends to emphasise more technique rehearsal, repetition and reproduction of movements. On the other hand, a more diverse and wide range of affordances are provided at the less specialised end of the performance landscape. Athletes need to be free to explore different and varied regions of their performance landscape in the achievement of task goals, to expand their effectivities. Enrichment of an athlete's effectivities may allow them to negotiate the dynamical landscape of competitive performance, which is always evolving. Hence, the more general ecology of a performance landscape, the greater will be opportunities for skill adaptation and synergy (re)formation amongst motor system degrees of freedom. Consequently, athletes will be able to expand their performance landscape, and thus, develop effectivities to exploit many varied, available affordances. This process of general athletic enrichment can help them to specialise and benefit from more specified coaching later in their development. Principles of NLP and ASM advocate a careful, nuanced, and continuous transition between generality (non-target sports and activities) and specificity (engaging with various forms of a target sport) of transfer needed in talent development programmes [11, 12].

Specialisation readiness is not necessarily dependent on a specific age, but on the developmental status of an individual learner at any point in time [16]. Even at the more specialist stage of athlete development—when athletes are on their development pathway (i.e. these stages are called specialising years (13–16 years) and investment years (+ 16 years)—they may need some generalised experiences to enhance their athleticism which might aid them to continue to specialise in their target sport despite effects of injuries, illnesses or ageing. Summarising, even at the general developmental phase, athletes may be exposed to some specialised experiences at an early age and at a more specialised training phase, individual athletes can benefit from some general athletic enrichment experiences. In contemporary motor-learning approaches (i.e. ecological dynamics) and pedagogical models (NLP and ASM), a clear bi-directional relational approach is advocated between the generality and specificity of skill acquisition and learning experiences throughout each individual's career.

5 Conclusions and Practical Applications

This Current Opinion proposed a model to develop talented athletes, grounded on key ideas from NLP and the ASM. If we are going to persist with TI rather than TD then, first, we need to develop ways of identifying general athleticism in young children and youth (general through assessing physical literacy). After being identified with some dispositional tendencies (abilities towards reaching expertise in specific sports), athletes can then be introduced to specialisation (bi-directional tendency between generality and specificity).

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Declarations

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References

1. Vaeyens R, Gullich A, Warr R, et al. Talent identification and promotion programmes of Olympic athletes. J Sports Sci. 2009;27(13):1367–80.
2. Baker J, Cobley S, Fraser-Thomas J. What do we know about early sport specialization? Not much! High Abil Stud. 2009;20(1):77–89.
3. Ericsson A, Krampe T, Tesch-Römer C. The role of deliberate practice in the acquisition of expert performance. Psychol Ver. 1993;100:363–406.
4. Coutinho P, Mesquita I, Fonseca AM. Talent development in sport: a critical review of pathways to expert performance. Int J Sports Sci Coach. 2016;11:279–93.
5. Roetert P, Woods B, Jayanthi A. The benefits of multi-sport participation for youth tennis players. ITF Coach Sport Sci Ver. 2018;26:14–7.
6. Davids K, Araújo D. Innate talent in Sport: beware of an organismic asymmetry: comment on Baker & Wattie. Current Issues Sport Sci. 2019;4:102.
7. Phillips E, Davids K, Renshaw I, et al. Expert performance in sport and the dynamics of talent development. Sports Med. 2010;40:271–83.
8. Rudd J, Pesce C, Strafford B, et al. An ecological dynamics rationale for individual enrichment: enhancing performance and physically activity in all. Front Sports Act Living. (**under review**).
9. Breitbach S, Tug S, Simon P. Conventional and genetic talent identification in sports: will recent developments trace talent? Sports Med. 2014;44(11):1489–503.
10. Davids K, Güllich A, Araújo D, et al. In: Baker J, Cobley S, Schorer J, Wattie N, editors., et al., Understanding environmental and task constraints on athlete development: analysis of micro-structure of practice and macro-structure of development histories. London: Routledge; 2017. p. 192–206.
11. Button C, Seifert L, Chow J-Y, et al. Dynamics of skill acquisition: an ecological dynamics rationale (2nd Edition). Champaign: Human Kinetics; 2020.
12. Chow J-Y, Davids K, Shuttleworth R, et al. Ecological dynamics and transfer from practice to performance in sport. In: Williams M, Hodges N, editors., et al., Skill acquisition in sport: research, theory and practice. 3rd ed. Routledge: London; 2020. p. 330–44.
13. Correia V, Carvalho J, Araújo D, et al. Principles of nonlinear pedagogy in sport practice. Phys Educ Sport Pedagogy. 2019;24(2):117–32.
14. Guignard B, Button C, Davids K, et al. Education and transfer of water competencies: an ecological dynamics approach. Eur Phy Educ Rev. 2020. https://doi.org/10.1177/1356336X20902172.
15. Hulteen M, Morgan J, Barnett M, et al. Development of foundational movement skills: a conceptual model for physical activity across the lifespan. Sports Med. 2018;48(7):1533–40.
16. Savelsbergh G, Wormhoudt R. Creating adaptive athletes: the athletic skills model for enhancing physical literacy as a foundation for expertise. Mov Sport Sci/Sci Mot. 2019;102:31–8.
17. Araújo D, Davids K. What exactly is acquired during skill acquisition? J Conscious Stud. 2011;18:7–23.
18. Davids K, Chow J, Shuttleworth R. A constraints-based framework for nonlinear pedagogy in physical education. J Phys Educ N Z. 2005;38:17–29.
19. McCosker C, Renshaw I, Russell W, et al. The role of elite coaches' expertise in identifying key constraints on long jump performance: how practice task designs can enhance athlete self-regulation in competition. Qual Res Sport Exerc Health. 2019;2:2. https://doi.org/10.1080/2159676X.2019.1687582.
20. Smith L. Specificity versus generality of relationships between individual differences in motor abilities. Educ Perspect. 1973;12:19–28.
21. Memmert D, Roth K. The effects of non-specific and specific concepts on tactical creativity in team ball sports. J Sports Sci. 2007;25(12):1423–32.
22. Memmert D, Baker J, Bertsch C. Play and practice in the development of sport-specific creativity in team ball sports. High Abil Stud. 2010;21:3–18.
23. Memmert D, Harvey S. Identification of non-specific tactical problems in invasion games. Phys Educ Sport Pedagogy. 2010;15:287–305.
24. Hüttermann S, Memmert D, Baker J. Understanding the microstructure of practice: training differences between various age classes, expertise levels and sports. Talent Dev Excell. 2014;2014(6):17–29.
25. Memmert D. Development of tactical creativity in sports. In: Baker J, Farrow D, editors. The handbook of sport expertise. Abingdon: Routledge; 2015. p. 363–72.
26. Chow J, Davids K, Button C, et al. Nonlinear pedagogy: a constraints-led framework for understanding emergence of game play and movement skills. Nonlinear Dyn Psychol Life Sci. 2006;10(1):71–103.
27. Wormhoudt R, Savelsbergh P, Teunissen W, et al. The athletic skills model: optimizing talent development through movement education. Milton: Routledge; 2018.
28. Chow JY, Davids K, Button C, et al. Nonlinear pedagogy: implications for teaching games for understanding. In: Hopper T, Butler J, Storey B, editors., *et al*., TGfU. Simply good pedagogy: understanding a complex challenge. Ottawa: Physical Health Education Association; 2009. p. 131–44.
29. Davids K, Glazier P, Araújo D, et al. Movement systems as dynamical systems: the role of functional variability and its implications for sports medicine. Sports Med. 2003;33:245–60.
30. Chow J-Y, Davids K, Hristovski R, et al. Nonlinear pedagogy: learning design for self-organizing neurobiological systems. New Ideas Psychol. 2011;29:189–200.
31. Davids K. Learning design for nonlinear dynamical movement systems. Open Sports Sci J. 2012;5:9–16.
32. Seifert L, Papet V, Strafford B, et al. Skill transfer, expertise and talent development: an ecological dynamics perspective. Mov Sport Sci/Sci Mot. 2019;102:39–49.
33. Kelso J. Dynamic patterns: the self-organising of brain and behavior. Massachusetts: MIT Press; 1995.
34. Araújo D, Davids K. Talent development: from possessing gifts, to functional environmental interactions. Talent Dev Excell. 2011;3:23–6.
35. Balagué N, Pol R, Hristovski R, et al. On the relatedness and nestedness of constraints. Sports Med Open. 2019;5:6. https://doi.org/10.1186/s40798-019-0178-z.
36. Pol R, Balagué N, Ric A, et al. Training or synergizing? Complex systems principles change the understanding of sport processes. Sports Med Open. 2020. https://doi.org/10.1186/s40798-020-00256-9.
37. Bernstein N. The coordination and regulation of movement. New York: Pergamon; 1967.
38. Araújo D, Dicks M, Davids K. Selecting among affordances: a basis for channeling expertise in sport. In: Cappuccio M, editor. The MIT Press Handbook of embodied cognition and sport psychology. Boston: MIT Press; 2019.

39. Renshaw I, Davids K, Newcombe D, et al. The Constraints-led approach: principles for sports coaching and practice design. Milton: Routledge; 2019.
40. Bruineberg J, Rietveld E. Self-organization, free energy minimization, and optimal grip on a field of affordances. Front Hum Neurosci. 2014;12(8):599.
41. Rothwell M, Davids K, Stone J, et al. The talent development process as enhancing athlete functionality: creating forms of life in an ecological niche. In: Baker J, Cobley S, Schorer J, editors. Talent identification and development in sport. International perspectives. 2nd ed. New York: Routledge; 2020.
42. Bloom B. Developing talent in young people. New York: Ballantine Books; 1985.
43. Côté J. The influence of the family in the development of talent in sport. Sport Psychol. 1999;13:395–417.
44. Côté J, Erickson K. Diversification and deliberate play during the sampling years. In: Baker J, Farrow D, editors. Handbook of sport expertise. London: Routledge; 2015. p. 305–16.
45. Côté J, Lidor R, Hackfort D. ISSP position stand: to sample or to specialize? Seven postulates about youth sport activities that lead to continued participation and elite performance. Int J Sport Exerc Psychol. 2011;7(1):7–17.
46. Balyi I, Hamilton A. Long-term athlete development: trainability in childhood and adolescence. Windows of opportunity Optimal trainability. Victoria: National Coaching Institute British Columbia & Advanced Training and Performance Ltd; 2004.
47. Travassos B, Araújo D, Davids K. Is futsal a donor sport for football? Exploiting complementarity for early diversification in talent development. Sci Med Football. 2019;2(1):66–70.
48. Oppici L, Panchuk D, Serpiello R, et al. Futsal task constraints promote transfer of passing skill to soccer task constraints. Eur J Sport Sci. 2018;18(7):947–54.