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Fostering Motor Development Through the Application of Nonlinear Pedagogical Design Principles in Primary Elementary Learners

Francis J. Lynott III, Sara A. Westerlin,
Gina L. Bittner, and Dawn L. Mollenkopf

Peru State College USA

Author Note

Sara A. Westerlin https://orcid.org/0000-0001-6940-3316
Dawn L. Mollenkopf https://orcid.org/0000-0002-8947-5728

Introduction

Scholars and practitioners agree that motor skill development is essential for children, beginning in early childhood. The early childhood stage of life is typically considered to be a range from birth through age eight and/or third grade (Britto et al., 2017; Copple & Bredekamp, 2009; Morrison, 2020). Motor development throughout the early childhood stage is important as it has connections to other areas of development such as cognitive, language, social/emotional development, and academic success (Essa & Burnham, 2020). Early childhood educators have the unique task of fostering motor development among their students. However, early childhood educators' further understanding of the vital role of motor development and how to effectively foster motor development is needed (Altinkok, 2017). Applying the fundamentals of motor skill development for children in the classroom setting can prove beneficial for both student and teacher. Herein, the authors will focus on what motor development is, how this manifests itself in young learners, the concept of the nonlinear pedagogy design principles, and the importance of the movement as it applies to educational principles and practice.

What is Motor Development?

Motor development can be understood as the development of motor skills. Motor skills are defined as "the underlying internal processes responsible for moving the body or parts of the body in space" (Cameron et al., 2016, pg. 93). However, motor skills are not simply bodily movements. They are in fact, the manifestation of the interaction of a multitude of cognitive processes with the neuro-muscular and musculoskeletal systems to meet the requirements of a directed action (Adolph & Berger, 2006; Lee et al., 2014). Motor skills are commonly divided into two groups:

Correspondence concerning this article should be addressed to Sara A. Westerlin, E-mail: SWesterlin@peru.edu.

a) *gross motor skills*, and *b*) *fine motor skills*. *Gross motor skills* are understood as movements that require the coordination of large muscle groups such as balancing, orientation and movement of limbs or the trunk, posture, and common locomotor movements like walking, running, jumping, or hopping (Burton & Rodgerson, 2001; Newell, 2020). *Fine motor skills* involve coordination of small muscle groups arising in movements like drawing, writing, speaking, or playing an instrument (Beery et al., 2010, Newell, 2020). A survey of current research indicates that gross motor skills are associated with children's developing social competencies, physical well-being, social learning skills, and positive attitudes toward active learning experiences (Cameron et al., 2016; Pagani & Messier, 2012; Rudd, O'Callaghan, & Williams, 2019). Concurrently, researchers report that fine motor skills are robustly associated with academic achievement, math, and reading skills (Cameron et al., 2016; Murrah, 2010). The development of gross and fine motor skills is also associated with the fostering of the cognitive processes that support school readiness and school performance.

COGNITIVE PROCESSES

These cognitive processes include, but are not limited to, *motor coordination*, *executive function,* and *visuospatial skills* (Cameron et al., 2016). *Motor coordination* is defined as the execution of multi-step tasks that require among other things, a child to coordinate body movements that may include the manipulation of an object in a directed action (Keinan et al., 2020; Marr et al., 2003). For the school-aged early childhood learner, developmentally appropriate tasks requiring motor control would include balancing, running, jumping, hopping, skipping, kicking, catching, volleying, and throwing (Newell, 2020). *Executive function* is understood as a set of neurological processes that helps children to focus and shift attention to information necessary for the successful execution of a presented motor goal (Perone et al., 2018). For example, a student may be presented with the motor goal of throwing a beanbag for a distance of at least five feet. As the learner experiments with various throwing patterns, the learner will then be afforded opportunities to discover motor patterns that help meet the motor goal. This could include differentiating the effectiveness of overhand or underhand throwing patterns and how the point of release of the bean bag affects trajectory. With the guidance of an instructor, the learner will then be able to better identify what type of throwing pattern or points of release to focus on and pay attention to. In doing so, the learner is exercising their executive function processes and fostering motor development.

Like motor coordination and executive function, *visuospatial skills* are a set of cognitive processes. However, *visuospatial skills* are unique in that they include the capability of an individual to perceive local aspects of a stimulus from a global context to meet the demands of a directed motor goal (Ip et al., 2017). For example, students could be presented with a series of motor skill goals to be executed in a school gymnasium where colored lines are taped on the floor. In this example, the gym would be considered the "global context" and the colored lines would be the "local stimuli" to be perceived to meet the motor goals. The motor goals would take the form of the teacher's directions. The teacher could first call out a color, such as green, and then a motor skill, such as skipping. The student would then have to examine the global context of the gym and then identify the correct color line, move to that line, and then execute the directed motor skill. The teacher could then call another color and another motor skill. For example, "Show me sitting on a red line." The students would then be required to reexamine the "global context," identify the correct colored line, move to that line, then execute the directed motor skill. In this case, to meet the motor goal, students will have to discern the red line from all other lines in the gym, move to that line then sit on it to be successful. In doing so, students would be provided with opportunities to practice, develop, and hone specific motor skills and visuospatial skills. A consensus exists that the development of motor skills is essential for the school-aged early childhood learners (Cameron et al., 2016; Rudd et al., 2019). One way to foster motor skill development is through the application of nonlinear pedagogical principles.

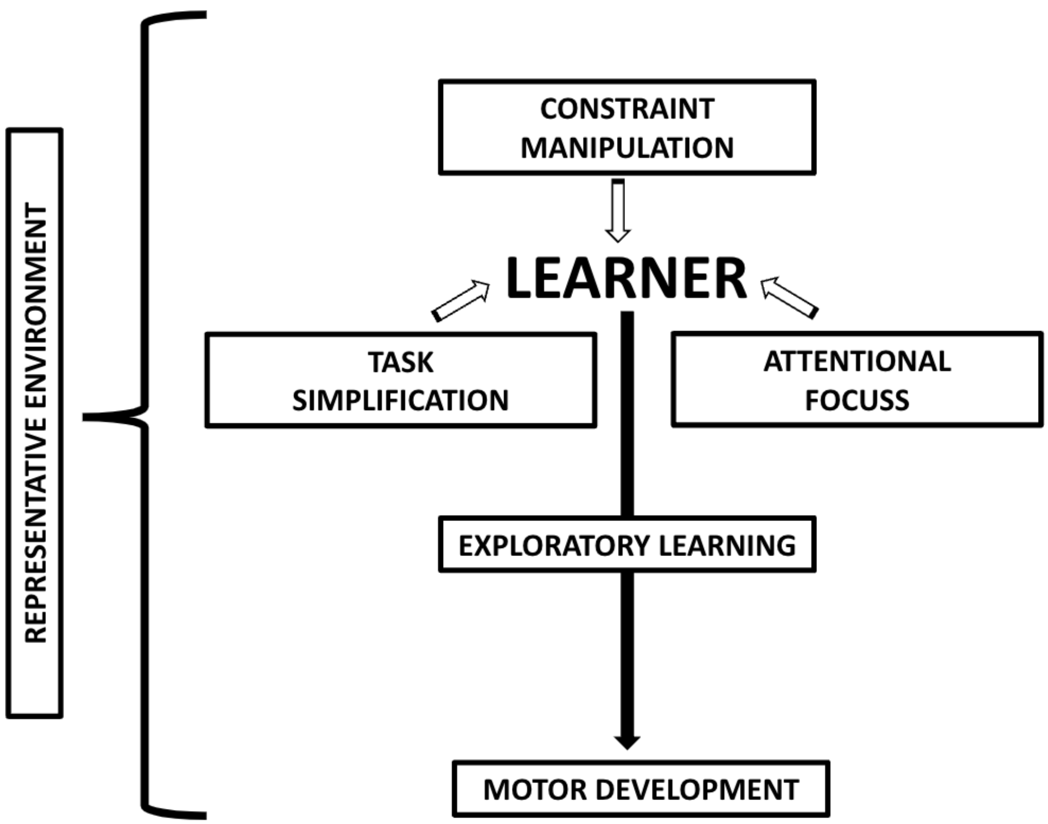
WHAT IS NONLINEAR PEDAGOGY?

Nonlinear pedagogy is a pedagogical framework that draws from the tenets of Dynamics Systems Theory. One of these tenets is that learning is the nonlinear interaction of the learner within the context of an environment and the resulting emergence of self-organized movement skill competencies (Brymer & Davids, 2013; Kugler et al., 1982; Lee et al., 2014; Rudd et al., 2019). In the framework of nonlinear pedagogy, motor skills are developed if practiced in a representative environment. A *representative environment* is one that is dynamic, like the context in which a motor skill would be applied, and the performer is having to negotiate and interact with organismic, physical and task variables collectively referred to as constraints as shown in Figure 1 (Button et al., 2021; Verhoeff et al., 2020). Unlike a more traditional linear approach toward motor skill development, the learner is not provided with a visual template of the movement or repetitive prescriptive practice sessions of a particular skill (Williams & Hodges, 2005). Instead, the learner is provided with opportunities to explore functional movement solutions for directed movement goals (Chow et al., 2007; Renshaw et al., 2010; Verhoeff et al., 2020). For example, a teacher could pose the following goal-directed behavior to an early elementary student: "Keep the balloon from touching the ground without holding it or trapping it with any body part." In this case, the learner is being provided an opportunity to engage in exploratory learning. As the learner explores and discovers movement patterns that prevent the balloon from touching the ground, functional motor movement patterns associated with the skill of volleying may be realized.

Researchers contend that providing early childhood learners with nonlinear learning opportunities like in the volleying example are advantageous for motor skill acquisition and development in three ways. First, learners are allowed to interact with the task in pursuit of a motor goal in a representative context (Chow et al., 2007). In the example of volleying a balloon, a representative context is constituted by the fact that environmental constraints like other students in the space or a breeze need to be negotiated by the learner to keep the balloon in volleying motion. This interaction with a dynamic, more realistic, or representative environment has been shown to be advantageous to motor development in comparison to a more static environment of a linear learning approach (Barab & Roth, 2006; Chow et al., 2007; Rudd et al., 2019).

Second, nonlinear learning opportunities are more student-focused; therefore, affording learners with richer opportunities to construct meaningful relations to the purpose, need, and function of a particular motor skill (Button et al., 2021; Sumara & Davis, 2006). In the balloon volleying example, the learner's exploration of movements and interactions with the environment to achieve the desired motor skill of volleying is the focus of the session. In a more traditional linear session, the mimicking and replication of the teacher's movements are the focus of the practice session, thereby making the session less student-centered. Researchers suggest that the exploratory student-centered learning inherent in nonlinear pedagogy has been shown to impact learners' motivation to engage and stay engaged in motor movement learning and physical activity opportunities (Rudd et al., 2019). Finally, nonlinear learning opportunities have been shown to support the development of *motor movement intelligence*. Motor movement intelligence can be understood as a learner's ability to take into consideration the constraints of the environment and how one's motor movements can be manipulated to successfully negotiate these constraints (Fajen et al., 2009; Stockl et al., 2011). In the balloon volleying example, the learner is required to negotiate the constraints of the environment to keep the balloon in volley. In doing so, the learner is provided with opportunities to gain insights and understanding about how they can adjust their movements to sustain the volley. Unlike a linear practice session where the environment is static, the dynamic representative environment of a nonlinear practice session may be more conducive for the development of motor movement intelligence. In summary, nonlinear pedagogy provides learners with a rich representative learning environment that is learner-focused and supports the development of motor movement skills.

Figure 1
Representative Environment



APPLICATION OF NONLINEAR PEDAGOGY DESIGN PRINCIPLES

Researchers from a broad array of studies contend that the application of nonlinear pedagogy design principles have potential benefits in the development of motor skills in a wide array of contexts (Button et al., 2021; Práxedes et al., 2018; Richard et al., 2018; Ip et al., 2017). Three of the pedagogical design principles identified by researchers as having a positive impact on motor development are: *a*) *task simplification*, *b*) *attentional focus*, and *c*) *constraint manipulation*.

Task Simplification

Task simplification can be understood as the systematic modification of task demands based on an individual's affordances to foster motor learning (Button et al., 2021). Typically, this entails making a challenging motor task simpler. This simplification of the task is systematic because task modifications are to be guided by a learner's current motor performance abilities. A learner's current motor performance abilities are referred to as affordances (Gibson, 1979; Withagen et al., 2017). Skipping is a complicated motor performance that requires, among other things, oppositional movement of limbs in conjunction with the execution of a one-footed hop where the performer lands on the opposite foot. Then, the performer repeats the sequence off the foot they landed on (Graham et al., 2010). According to the Center for Disease Control's (CDC) Milestone Checklist, by age five, a child should be able to hop and skip as an emerging skill (CDC, 2020). If a learner can perform a one-footed hop but is not yet able to skip, hopping is an affordance that can be built upon. In this example, it would be appropriate to next introduce the concept of the oppositional limb movement. Learners could be tasked with the following movement behavior, "When you land on your foot, raise your opposite arm." In doing so, the task of skipping is simplified based on the learner's affordances. Once the hop and limb opposition pattern has been integrated, the performance of the sequential alternating repetition of the skipping elements could be tasked to the learner. This skipping learning sequence previously described demonstrates the systematic modification of a complicated performance based on a student's affordances. Although this example is based on a particular learner's set of affordances related to skipping, the concept of task simplification can be applied to learners despite their existing affordances in the development of all motor skills.

Attentional Focus

Attentional focus is another principle that has been described as a "potent tool for developing skill from a nonlinear pedagogy perspective" (Button et al., 2021, pg. 116). This principle is based on the assertion that a learner's focus can be classified as being either *internal* or *external*. An *internal focus* is one in which a learner's attention is on the various bodily movements that collectively result in the desired motor skill (Button et al., 2021; Wulf & Lewthwaite, 2016). For example, if a learner is tasked with catching a ball, the learner might be guided by the instructor to focus on hand placement and/or arm extension during the catching attempt. If the attempt at catching was not successful, the learner would then be provided with repetitive catching opportunities with prescriptive instruction regarding the placement of the hands or the extension of the arms.

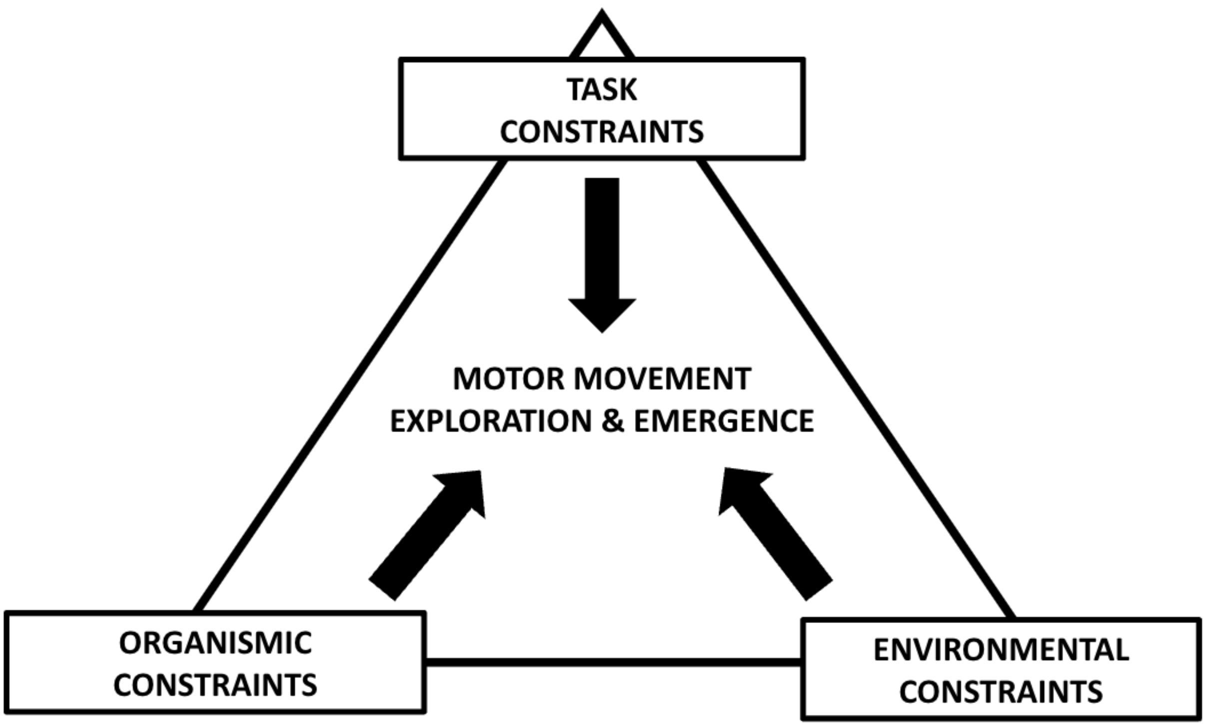
Although this linear pedagogical approach that features an internal focus is widely accepted and practiced, researchers contend that a nonlinear pedagogical approach with an *external focus* may be beneficial to learners (Adollahipour et al., 2017; Button et al., 2021; Wulf & Lewthwaite, 2016). An *external focus* is one in which the learner's attention is on the successful execution of a motor skill and the direct effects of their actions (Wulf, 2007, 2013; Adollahipour et al., 2017). Referring to the task of catching a ball, the learner's attention in an externally focused practice session is not on bodily movements but on successfully meeting the task objective. For example, if the attempt to catch the ball was not successful, the learner would be guided to identify and try other movement patterns in the form of instructor feedback. The feedback provided is not necessarily prescriptive or corrective regarding specific bodily movements. The feedback is however, used to support the learner's exploration of movement patterns that support achievement of the task goal. In doing so, learners are provided with an exploratory learning experience. It is theorized that in an externally focused exploratory learning environment, the learner is not distracted by concentrating on specific bodily movements and is more likely to experience task success (Adollahipour et al., 2017; Chiviacowsky, & Toaldo Gentilini Avila, 2012; Neumann, 2019; Wulf & Lewthwaite, 2016). In the framework of nonlinear pedagogy, an exploratory learning experience coupled with an external focus has been shown to be effective in the development of motor skills in early childhood learners.

Constraint Manipulation

Constraint manipulation is identified as an important principle in nonlinear pedagogy (Button et al., 2021; Pol et al., 2020; Verhoeff et al., 2020). From a nonlinear pedagogical perspective, a *constraint* can be conceptualized as a contextual variable that is both a limiter and a catalyst of motor movement exploration and motor movement emergence as seen in Figure 2 (Seifert et al., 2013; Verhoeff et al., 2020). Three types of constraints are *organismic constraints*, *environmental constraints,* and *task constraints* (Newell, 1986). *Organismic constraints* refer to the characteristics of the individual who is tasked to execute a motor skill. Organismic constraints include characteristics, such as weight, limb length, percentage muscle mass, or flexibility (Balagué et al., 2019; Davids & Araujo, 2010). Researchers contend that some organismic constraints are more modifiable than others. For example, if a learner lacks the prerequisite flexibility needed to touch one's toes, the learner can then be provided with learning experiences that foster the needed range of movement. *Environmental constraints* refer to the variables inherent to the locale of where a motor action is to be performed (Button et al., 2021; Pol et al., 2020; Rudd et al., 2019; Verhoeff et al., 2020). This includes but is not limited to weather conditions, lighting, performance surface, other people or objects in the area, the presence or lack of auditory and visual stimuli, and the defined physical parameters of where the motor performance is to take place. For example, motor learners could be tasked with the performance of a skill in an indoor setting, like a gym, or in an outdoor setting, like a field or playground. Whether in or out-of-doors, each locale has a unique set of constraints. For example, task constraints are usually defined as those specified by the task to be performed (Balagué et al., 2019). Ball size and shape, specific goals to be achieved, boundary lines, playing field length, number of opponents and teammates involved, situational characteristics of opponents such as players' relative position, rules and protocols can all be considered tasks constraints can all be examples of task constraints (Balagué et al., 2019; Pol et al., 2020). The manipulation of constraints is referred to as the constraints-led approach and is said to be "a powerful aspect of nonlinear pedagogy for encouraging transitions toward, and acquisition of, new preferred stable movement behaviours" (Button et al., 2021, p. 115). The concept of a constraint-led approach, while being both a catalyst and a limiter, offers motor movement exploration through the important pedagogical structures of both linear and non-linear approaches.

One movement behavior that the constraint-led approach can be implemented with is balancing. Balancing is considered a non-locomotor motor skill that has been associated with cognitive skill development and academic success in early childhood learners (Cameron et al., 2016; Veldman et al., 2019). It is theorized that the act of balancing requires the mover to integrate *motor coordination*, *executive function,* and *visuospatial skills* to meet the demands of the motor task assigned; therefore, providing learners with the opportunity to develop these cognitive skills (Cameron et al., 2016; Pagani, & Messier, 2012; Rudd et al., 2019; Veldman et al., 2019). The constraint-led approach can provide learners with rich and engaging opportunities in the development of balancing. As previously stated, organismic constraints are constraints that can be conceptualized as innate, and highly individualized characteristics of a specific learner. One way to manipulate these constraints is through the differentiation of motor goals associated with balancing. For example, in a class of learners, balancing abilities may vary. Some learners may find it challenging to balance on one foot while others may demonstrate differing levels of proficiency. Considering the organismic constraints of balancing proficiency, the teacher could then provide individual students with differentiated motor goals associated with balancing. Differentiation based on organismic constraints provides students with opportunities to engage in learning opportunities that are adapted to their needs and have been shown to be engaging and beneficial to the learner (Arefiev et al., 2020; Button et al., 2021).

Figure 2
Constraint Manipulation



The manipulation of environmental constraints is another technique that could be employed in the development of balancing skills. As previously defined, environmental constraints consist of the characteristics of the locale of where a motor skill is to be performed. One environmental constraint that can be manipulated is the surface for which learners balance. For example, learners could be tasked with balancing goals on a stable, relatively flat surface like the gym floor. Learners could also be tasked with the same balancing goals on less stable and uneven surfaces. These could include surfaces found outside of the gym, such as on gravel, grass, carpets, or on uneven surfaces. Manipulating the environmental constraint of the surface provides students the opportunity to discover motor patterns through non-linear experiential learning that helps them to meet the motor goal they have been tasked with.

Additionally, manipulation of task constraints offers a third way to foster the development of motor skills in learners (Button et al., 2021). Regarding the development of balancing skills, task constraints can be presented to learners in the form of movement goals. For example, a teacher could task a student with a goal of demonstrating balancing on one foot. In this scenario, students would choose a foot to accomplish the goal with. Next, the teacher could task the students to then balance on the other foot. In doing so, students are provided with a task constraint that encourages the further development of the skill of balancing. In addition, the teacher could allow for free exploration or guide students to discover other body parts they could balance on. Also, depending on the environment, the teacher would need to remind the students of the boundaries in which they can perform the task, such as putting cones or flags down in a field, using the lines in the gymnasium, or using natural landmarks such as trees or bushes, to allow students to practice their task of balancing within those constraints.

Closing

As shown, early childhood educators have the unique task of fostering motor development among students in their classrooms and center facilities. To effectively do so, it is imperative that these educators take the time and initiative to understand and appreciate the role that motor development combined with cognitive development, plays in fostering learning and age-appropriate development. Understanding that motor skills are not just bodily movements, but instead create a symbiotic relationship between motor skills and cognitive processing, allows early childhood educators to coordinate motor coordination, executive function, and visuospatial skills to design and develop age-appropriate learning environments. Furthermore, by using the nonlinear pedagogical principles of task simplification, attentional focus, and constraint manipulation, early childhood educators can key in on the critical aspects of motor skill development for both fine- and gross-motor skill needs. Motor development throughout the early childhood years is critically important as it connects to other areas of development, such as cognitive, language, social/emotional development, and academic success; therefore, applying the fundamentals of motor skill development for the youngest learners can prove beneficial for both educators and their students.

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