LEARNING MOTOR SKILL IN PHYSICAL EDUCATION

Catherine D. Ennis and Ang Chen

INTRODUCTION

Magill (2009) defined motor skill learning as “a change in the capability of a person to perform a skill that must be inferred from a relatively permanent improvement in performance” (p. 169). Research has provided evidence that practice is the single most important factor responsible in learning to perform a motor skill (Barnett, Ross, Schmidt, & Todd, 1973; Del Rey, Wughalter & Whitehurst, 1982; Fitts, 1954; Guadagnoli, Holcomb, & Weber, 1999; Krigolson & Tremblay, 2009; Starks, 2000; Swanson & Lee, 1992). Practice effectiveness, however, is related to how it is structured and the type, timing, and amount of feedback the learner receives while practicing (French, Rink, Rikard, Mays, Lynn, & Werner, 1991). (See also Chapter 14 in this volume, “Instruction Based on Feedback.”) Maximizing the quality of the learner’s skill practice opportunities is a primary goal of physical education teaching.

In this chapter, we examine and critique research evidence from motor skill learning research. First, we provide historical background documenting the evolution of motor skill learning research. We then explain evidence-based research in motor skill learning guided by the theoretical frameworks of information processing, expert-novice comparison, and dynamical systems theories. Today, because few physical education learning goals are oriented toward learning isolated motor skills, we review research examining learners’ tactical decision-making within complex games environments and the role of learner thought processes in acquiring motor skills. In the final section, we articulate the potential of conceptual change research to advance our understanding of motor skill learning in physical education.

HISTORICAL OVERVIEW

Beginning in the 1930s, research examining motor skill learning focused on the development of objective tests of motor ability and educability and the identification of critical variables that enhance learning and performance. Motor educability was defined as the strength, ability, and coordination necessary to perform motor skills effectively. Early motor skill researchers focused on identifying skill components and effective
practice contexts to increase students’ learning and performance. In 1972, Gentile proposed a three-stage model of skill learning based, in part, on these early studies. In stage 1 of Gentile’s theory, the learner acquires an idea of the movement in terms of skeletal-muscular relations of body parts as explained in teacher demonstrations and explanations. In stage 2, the learner’s goals change to reflect the relation between the body movement and the environment in which the skill is performed. In stage 3, performance becomes automatic as the learner focuses attention on the continuous, rapidly changing temporal and spatial environmental conditions that develop with concomitant movements of the object and other players in relation to the goal. At this third automatic stage, the teacher/coach becomes peripheral to the skill learning process.

These stages differentiate between two types of skills: closed and open (Farrell, 1975). In closed skills, both performer and context are stationary at the beginning of the skill, such as in a diving from a 3 m board. Conversely, in open skills both the performer and the context are moving, such as in dribbling against the press in basketball. Applying Gentile’s (1972) skill acquisition theory to a closed skill, such as a golf swing, requires the learner to strive for “fixation” to perform the movement pattern consistently (stage 1; Del Rey, 1972, p. 42). The movement goal when executing the golf swing is to execute the swing essentially the same way whether using a driver or an iron. In stage 2, the learner continues to reduce the variability in the movement pattern or to bring the movement pattern into conformity with an externally imposed environment (distance to the hole, slope of the golf course). Because the environment is stable, the learner is able to determine the body-environment relations prior to skill execution. Stage 3 is rare in closed skill performance because of the absence of temporal and spatial changes at the moment of skill execution.

Conversely, when learning an open skill, the stages begin to differentiate after stage 1. In stage 2, the learning goal is motor pattern “diversification” (Del Rey, 1972, p. 42). Because the environment is changing moment by moment, the learner must rely on external feedback (knowledge of performance) to develop many diverse motor patterns, each one appropriate to a particular set of temporal and spatial conditions. Gentile (1972) emphasized that in open-skill tasks, no single motor pattern would accomplish the movement goal under all possible conditions. At stage 3, open skill performance becomes automatic as the learner internalizes knowledge of performance and focuses attention, instead, on environmental conditions that impact skill execution. Physical education research to enhance skill learning based on Gentile’s model, therefore, focuses primarily on stage 2 as the learning stage in which teacher feedback is most useful. Feedback at this stage is critical because it informs the learner of relative body component positioning and environmental changes related to skill performance. To provide appropriate feedback, researchers and teachers need to understand the elements of each skill and how best to direct learners’ attention and movement to enhance performance.

Consistent with these assumptions, researchers (e.g., Roberton, Halverson, Langendorfer, & Williams, 1979) examined the actions of specific body parts to analyze learners’ skill development. To establish performance models for effective feedback, many isolated skills, such as the overarm throw, were analyzed using elite performers (professional baseball pitchers) to identify how each body component should move to meet criteria of distance or velocity, for example. The body-component model was based on the separation of skills into discrete parts conducive to corrective feedback applications. Roberton et al.’s (1979) research examined skill coordination and control variables of the overarm throw. They filmed children of different
ages and abilities using the overarm throwing pattern to identify body component movements associated with the development of throwing speed and accuracy. They determined hierarchical stages of throwing efficiency using qualitative biomechanical analysis of high-speed film of student throwers at diverse stages of overarm throwing development.

Advocates of body-component analysis developed extensive cuing systems that focused learner attention on the relations of body parts, shaping movements to reflect a universal, ideal pattern. For example, Table 8.1 shows a cueing chart for teaching the overarm throwing pattern recommended by Knudson and Morrison (1996). In column 1, they listed the critical features or biomechanical characteristics of effective performance, while column 2 translated the biomechanical concepts into teaching cues reflecting a body component feedback model. When teaching from the body component model, teacher feedback emphasized the relative position of body parts to produce a developmentally appropriate overarm throw. Unlike the tasks developed by Mortimer (1951) to induce arc of flight, this cueing system did not focus on the throwing context. Instead, the teacher used cue words and phrases (“step as you throw”) to focus learner attention on the body parts involved in the pattern. Less attention was given to context-based cues such as “look at the target” or “point to the target” as the ball is released, all effective contextual cues to increase children’s throwing accuracy.

A primary purpose of learning motor skills in physical education is to apply or transfer skills into effective game play and fitness activities (Stodden, Langendorfer, & Robertson, 2009). Learners, however, must have extensive experiences within increasingly more complex games to transfer skills successfully. Much of the early research examined isolated skills, such as the basketball jump shot or the overarm throw. Researchers assumed that ability to perform the skill in isolation would transfer into the complex game. Additionally, research subjects typically were advanced performers who provided ideal models of skillful performance. The goal was to teach novice adults and children to perform the skill within the adult expert model.

In physical education, however, many learners are child and adolescent novices. Understanding how adults or experts throw or hit the ball does not help the teacher know how children learn skills in complex social environments, such as team games. Among the initial challenges was the quest to describe variables that differentiated more versus less skilled performance. Tests of educability and gross motor ability, for example, were used to determine basic differences among performances in agility, speed, and coordination. These measures displayed limited validity and reliability when compared with more precise measures used today.

<table>
<thead>
<tr>
<th>Critical Features</th>
<th>Cues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg drive and opposition</td>
<td>Step with the opposite foot, turn your side to the target</td>
</tr>
<tr>
<td>Sequential coordination</td>
<td>Uncoil the body</td>
</tr>
<tr>
<td>Strong throwing position</td>
<td>Align arm with shoulders</td>
</tr>
<tr>
<td>Inward rotation of arm</td>
<td>Roll the arm and wrist at release</td>
</tr>
<tr>
<td>Relaxation</td>
<td>Relax your upper body</td>
</tr>
<tr>
<td>Angle of release</td>
<td>Throw up an incline; throw over the cutoff’s head</td>
</tr>
</tbody>
</table>
Additionally, early researchers’ emphasis on description of isolated skills rather than the performance of skills in game contexts constrained teachers’ understanding of context-focused (external) feedback necessary to increase the quality of game play. Finally, because university professors with access to college-age populations conducted most research, there were few studies during this time other than those by Roberton and her colleagues (1979) examining children’s movement patterns and development. Thus, children were taught to move based on elite, adult movement models rather than developmentally appropriate patterns such as those that Roberton (1982) described.

THEORETICAL FRAMEWORKS

Motor skill learning is characterized by incremental gains in performance on specific tasks (Schmidt & Lee, 2011). Success in learning relies on a process called neural and behavioral organization or neural-behavioral programming (Jeanerod, 1988; Schmidt & Lee, 2011). From this perspective (Jeanerod, 1988), learning any motor skill is an effort with combined cognitive and physical involvement, advancing from the initial perceiving, coordinating, and receiving feedback; to coding and recoding a sequence; and finally to controlling the movement to meet the goal of the action. The programming process is considered to be hierarchical, with the cognitive function of the brain constantly controlling the physical behavior. Any contextual factors influencing the cognitive functions eventually will influence the neural-behavioral programming. The influence of cognitive psychology on neural behavioral motor learning theories is evident in this work. Under this influence, scholars have applied three models to explain and guide learning in the psychomotor domain: information processing, expertise-novice comparison, and dynamical systems.

Information-Processing Frameworks

Beginning in the 1970s and continuing today, information processing theory has been used extensively to generate performance models examining variables and mechanisms relevant in motor skill learning. In this section we describe several research studies examining two skill learning variables, feedback and contextual interference, influential in motor skill learning.

Feedback

A very large body of research has examined feedback types, conditions, and delivery systems within motor performance learning (Hebert & Landin, 1994). Feedback can be used to enhance particular types of motor skill learning within certain practice conditions (Magill, 2009). Feedback is defined as knowledge of results internally or externally focused to enhance motor skill learning. Feedback includes information from sources that are internal to the performer (e.g., sensory or kinesthetic) and typically available during the performance. Other forms of feedback from sources not usually available to the learner during the performance can be augmented or provided by an external source, such as the teacher or coach. Motor skill learners and sport performers actively seek information from internal and external sources to adjust movements based on the movement goal or problem to be solved within rapidly changing environments of differing complexity.
A fundamental assumption of learning in the psychomotor domain is that “learning is a problem-solving process in which the goal of an action represents the problem to be solved and the evolution of a movement configuration represents the performer’s attempt to solve the problem” (Guadagnoli & Lee, 2004, p. 213). From this perspective, skills practiced in isolation within the laboratory or gymnasium reflect an overly simplified task without the complexity inherent in complex game, adventure, dance, or aquatic environments. For example, when the problem is associated with accuracy, the solution typically depends on external effect-related feedback rather than internal or body component feedback.

Research by Wulf, McConnel, Gärtner, and Schwartz (2002) demonstrated the value of effect-focused feedback to enhance learning and performance by comparing the effectiveness of two types of augmented feedback on performers’ attention focus and performance accuracy. Augmented feedback consisted of specific feedback directed to body movements (internal-focus) or to movement-effects (external focus). In Experiment 1, groups of novices and advanced volleyball players (N = 48) practiced serves under the internal focus or the external focus feedback conditions in a 2 × 2 (Expertise × Feedback type) design. They found that although type of feedback did not affect movement quality, external-focus (contextual) feedback resulted in greater serve accuracy than did internal-focus (movement of body parts) feedback during practice and retention conditions independent of performer skill level.

In Experiment 2, Wulf et al. (2002) examined the effects of relative feedback frequency as a function of attentional focus. In this experiment, a 2 × 2 (Feedback Frequency: 100% vs. 33% × Feedback Type) design was used. Experienced soccer players (N = 52) shot lofted passes at a target. Again the researchers concluded that external-focus feedback resulted in greater accuracy than internal-focus feedback. Additionally, reduced feedback frequency was beneficial under internal-focus feedback conditions, whereas feedback provided for 100% of the trials vs. 33% of the time were equally effective under the external-focus conditions.

Wulf et al.’s (2002) research demonstrated the value of effect-related (product) as opposed to movement-related (process) feedback when learning to perform with greater accuracy. Researchers advised teachers to minimize use of body components feedback (internal), instead focusing learners’ attention on the task product or task goal. Wulf et al. (2002; Wulf & Su, 2007) also have provided evidence that effect-related feedback is effective when learning both open (skiing) and closed skills (golf). For example, learners performed a golf pitch shot more accurately when their attention was directed to the motion of the club head rather than the swinging motion of the arms (Wulf, Lauterbach, & Toole, 1999).

These research findings indicate that effect-focused models of feedback delivery could assist learners to perform with greater accuracy. Historically, teachers and coaches have emphasized movement-related feedback (“keep your arms straight”) when learning accuracy related tasks, rather than directing the learners’ attention to the movement outcome (“when putting, look at the hole, not the ball”). Much of the feedback research, however, has not been conducted in educational learning environments, but instead in laboratories with novel tasks in which reaction time, for example, is used as a measure of attentional demand (Wulf, McNevin, & Shea, 2001). In the laboratory, the less burdened the learner’s autonomic system, the faster the reaction time and the greater degree of automaticity, reflecting Gentile’s (1972) third stage of automatic performance.
Transferring isolated skills to complex sport environments is highly demanding both physically and cognitively. Although applying feedback cues to whole-body movements with the appropriate timing and force production needed to perform with accuracy in open sport environments is challenging for adult experts, it is an overwhelmingly complex task for novice learners in physical education. Examining children's motor skill learning in the gymnasium gains the advantage of authentic context, while losing the precision of novel laboratory tasks and controlled conditions. Additionally, because motor skill learning researchers often examine performance variables using adult or elite learners, we have less evidence-based research to confirm the generalizability of these findings to school age populations in physical education.

**Contextual Interference**

Researchers studying motor skill learning have examined several practice variables in addition to feedback (e.g., motivation, attention, and contextual interference) that influence this dynamic process. Contextual interference (CI) within practice situations involves measures of retention and transfer across different skills, contexts, and time-frames. For example, researchers have focused on practice schedules that lead to initial learning and to skill retention within different sport contexts and over varying time periods (French, Rink, & Werner, 1990). Findings indicate that three practice conditions, blocked (BLO), alternating (ALT), and random (RAN), lead to differences in transfer of isolated skills to complex game environments. In BLO schedules, the learner practices one skill, while ALT and RAN schedules require learners to practice two or more different skills in alternating or random order. Although ALT and RAN practice schedules more closely reflect game complexity, they may not permit novice learners to establish an initial consistent motor pattern, thus inhibiting initial motor pattern learning. The ALT and RAN conditions are used quite effectively to create “contextual interference” with intermediate and advanced learners facilitating or disrupting transfer of motor skills to more complex situations.

Although many studies have examined practice schedules and contextual interference in the laboratory (e.g., Hall & Magill, 1995; Russell & Newell, 2007), research conducted to examine the effectiveness of contextual interference in physical education also can inform instruction. For example, Hebert, Landin, and Solmon (1996) examined the effects of practice schedule manipulation on the performance and learning of low and high skilled students. College undergraduates enrolled in five tennis classes performed a pretest on the forehand and backhand basics such as the grip, preparation, and swing. They responded to a questionnaire to self-assess their experience level in tennis and in other open skills (racquetball, softball), and rated the perceived difficulty of learning to play tennis.

Following the skills pretest, students were taught the forehand and backhand skills during the first three class periods. Learners were categorized into high- and low-skill groups, and assigned to BLO or ALT practice schedules. Students began each of the next nine lessons by performing 30 ground strokes: 15 forehand and 15 backhand. High and low skilled students assigned to the BLO condition completed all forehand strokes followed by all backhand strokes, while the ALT condition group alternated forehand and backhand strokes on each trial. Trials were scored as successful when the ball was propelled over the net, landing in the backcourt. Students completed a posttest following the nine classes.
Practice success was analyzed using a $2 \times 2 \times 3$ (Skill level $\times$ Practice Schedule $\times$ Test) design with repeated measures on the last factor. Results indicated that high-skilled students had significantly more success than low-skilled students in both practice conditions. Low-skilled learners assigned to the BLO schedule scored significantly higher on the posttest than low-skilled students assigned to the ALT schedule. There were no differences in posttest performances of high skilled learners assigned to the BLO or ALT condition. The researchers concluded that low interference (BLO) practice enhanced the learning of low-skilled students, while high-skilled learners demonstrated no posttest difference regardless of practice condition. Magill and Hall (1990) argued that high interference conditions are too complex for novices who have not established a basic motor pattern and, thus, are unable to benefit from the ALT and RAN conditions. Some experience or expertise is a prerequisite for learners to benefit from high interference practice schedules.

Information-processing researchers have examined the dynamics of sensory and augmented feedback and practice schedules with college and adult learners. Most research studies involve feedback delivery systems in which knowledge of results or corrective feedback is provided by the researcher to a single learner immediately following the performance. This is an optimal feedback condition that often cannot be replicated in physical education where one teacher may observe 25 or more diverse learner performances. The generalizability of laboratory findings has not been confirmed in research conducted in physical education classes (Silverman, Woods, & Subramaniam, 1998). For example, Silverman, Tyson, and Krampitz (1992) investigated the relations between teacher feedback and middle-school students’ achievement. Students in 10 middle-school physical education classes were pretested, received seven instructional lessons, and were posttested on two volleyball skills, the serve and forearm pass. Instruction was videotaped and teacher feedback subsequently was coded using a validated six-category (type, form, time, referent, number of students, and quality) observation system. Data were analyzed to reveal the relations of various feedback patterns to achievement. Results indicated that most students received relatively little skill-related feedback (approximately four times each lesson) and that total feedback, alone, did not relate to student achievement. Instead, the practice amount and quality proved to be more instrumental in student achievement of these two skills.

Teachers in these 10 middle-school classes emphasized traditional internally focused feedback directed toward manipulations of body components (corrective, specifically descriptive and prescriptive) feedback, rather than the typically more successful externally focused or context-oriented feedback. This may have been a limiting factor in feedback effectiveness. The Silverman et al. (1992) research was a correlational study that monitored, but did not manipulate, the instruction and types of feedback used. Controlled experimental designs can provide a better understanding of these factors’ contribution to motor skill learning.

**Expert-Novice Comparison**

Differences in sport skill execution are readily evident when comparing the performances of experts with those of novices (McPherson, 1999; McPherson & Thomas, 1989). Research examining low- and high-skilled learner differences in response to differing interference practice schedules has provided additional support for theories comparing novice and expert performance. Expert-novice frameworks that shift the research focus from expert performance to novice learning facilitate the search for
neural-behavior determinants of performance excellence. In addition to laboratory examinations of skill programming mechanisms, researchers also have studied skill learning on the field and gymnasium to define expertise as skill performance on more authentic performance tasks (Allard & Starkes, 1991).

It is well established that advanced performers are more capable of performing skillfully in isolated drill situations than their lesser skilled counterparts. Often the differences can be attributed to prior experience, superior strength, and greater coordination and control of physical movements. Based on findings from an extensive program of research, Ericsson (Ericsson & Kintsch, 1995; Ericsson, Krampe & Tesch-Römer, 1993) argued that extended engagement with a particular domain leads to the accumulation of domain-specific knowledge. Vaeyens, Lenoir, Williams, and Philippaerts (2007) explained that the development of “memory skills promote rapid encoding of information in long-term memory and afford selective access to that information when required” (p. 395). Ericsson concluded that skilled performers develop more flexible and detailed memory representations than do less skilled individuals, permitting them to adapt more readily to changing situational demands. Expert-novice comparisons of key variables associated with learners’ tactical decision-making can provide insight into superior playing ability in complex game environments.

Vaeyens and his colleagues (2007) investigated Ericson’s hypothesis in research to examine the complex interactions between perception, cognition, and expertise in novice and advanced youth soccer players. Previous research by Williams and his colleagues (Ward, Williams, & Bennett, 2002; Williams, Hodges, North, & Barton, 2006) found distinct differences in low- and high-skilled players’ ability to recall patterns of play, use visual search patterns, monitor opponent’s postural orientation prior to key events, and anticipate event outcomes (Ward & Williams, 2003). Vaeyens et al. (2007) investigated one hypothesized advantage that skilled performers appear to have when compared to less skilled, namely that of superior visual search behaviors that precede tactical decisions. Specifically, they hypothesized that successful players would exhibit a higher search rate and more frequent alternations of fixation between display areas than would their less successful counterparts.

Vaeyens et al. (2007) examined visual search strategies in three groups of 14-year-old male soccer academy players, representing elite, sub-elite, and regional playing ability. Players were tested using film-based simulation sequences of offensive soccer plays. Simulations consisted of offensive patterns of play with variations in the positions and ratio of attackers to defenders (2 vs. 1, 3 vs. 1, 3 vs. 2, 4 vs. 3, and 5 vs. 2) and length of play sequence. A panel of seven elite youth coaches determined the scoring system and later scored players’ performances for response accuracy, the dependent variable.

Visual scanning data were collected using an eye-head integration system with a head tracker to measure and record eye line of gaze in relation to head movements as players scanned the field while viewing the simulation. Players viewed a near-life size image of each scenario projected on a wall and responded physically to the sequence by either passing the ball toward the player on the screen, shooting on goal, or moving to dribble around a defender. Players verbalized their intended responses immediately following each trial. Each player viewed 33 offensive patterns in a randomized order kept constant for each participant.

Results indicated that more skillful learners were quicker to make decisions across all viewing conditions. Decision times for all learners were slower when responding to more complex situations involving multiple offensive and defensive players (3 vs. 2, 4 vs. 3). Further, analyses revealed that more skillful learners made more accurate
decisions than their less skillful counterparts in all viewing conditions. Similarly, more skillful learners used a more exhaustive search pattern involving a higher number of fixations than did their less skillful counterparts. As situations increased in complexity, fixation and inter-fixation durations and decision times increased for both more and less skillful players. More skillful players alternated their gaze more frequently between the player in possession of the ball and other areas of the field than less skilled players. Further, more skillful players spent less time fixating on the ball, instead fixating on the player in possession of the ball and on offensive players most closely marked by a defender.

One serious limitation of this research is the absence of a transfer test to determine if these results are applicable to actual playing settings. Expert-novice research also is limited by the opportunity to examine performances of established experts. In the Vaeyens et al. (2007) study it is questionable whether elite 14-year-old players are experts. It is likely that they would not be categorized in the expert group when competing against adult professional soccer players, for example. Additionally, it is unclear whether learners in physical education can be taught to use visual search techniques to improve their success in class games. Because learners in physical education typically reflect a wide range of technical skill and decision-making ability with a high preponderance of novice learners, effective instructional strategies should be examined with heterogeneous learners in modified and complex game situations. It is unclear at what point novice learners of any age can be taught to inhibit their tendency to focus on the ball and to employ more sophisticated visual strategies. Additionally, because expert-novice comparative research often is conducted with adolescents, it is not clear how visual search and decision-making strategies develop in children.

Vaeyens et al.’s (2007) research, however, does add support to the simple-to-complex instructional progression strategies advocated by many physical educators (Griffin & Butler, 2005; Griffin, Oslin, & Mitchell, 1997). One aspect of simple-to-complex game strategies is to begin with 2 vs. 1 and 3 vs. 1 modified games, adding offensive players first, and then defensive players, gradually increasing game complexity. Results from the Vaeyens et al. (2007) research are particularly informative for middle and high school physical education. Historically, many of these teachers have used large-sided games (11 vs. 11 soccer; 5 vs. 5 basketball) instead of using small numbers of players (small-sided games) and simple-to-complex instructional progressions as adolescent learners demonstrate their ability to transfer skills and decision-making ability from skill and tactical drills into small-sided games. It is likely that most middle- and high-school learners are not as skilled as Vaeyens’ lowest skilled group. Thus, based on findings from Vaeyens et al.’s (2007) research, low and moderately skilled adolescents in middle- and high-school physical education may be more successful in small-sided playing situations.

**Dynamical Systems Perspective**

Critics of the information-process and expert-novice comparison theories (e.g., Turvey, Fitch, & Tuller, 1982) argue that using pre-determined motor programs when executing motor tasks is inadequate. Like Gentile (1972), they emphasize that movement (i.e., open skill) is not a pre-programmed action sequence residing within an acquired knowledge structure or movement repertoire (Turvey et al., 1982). Thus, it is impossible for one to preselect a movement sequence from memory when facing novel or complex tasks. Instead, movements emerge from the constraints and affordances
naturally occurring in the environment. Although laboratory-based studies attempt to recreate natural or emergent sporting environments, laboratory environments still may not be authentic. In laboratory situations, the fabricated variables can only mediate (Magill & Hall, 1990) rather than determine skill execution as in authentic performance settings. In dynamical systems theories, the individual learns or performs motor skills within the constraints of biological, physical, and social environments. From this ecological perspective, motor sequence is hypothesized as an emergent consequence of action resulting from interactions between the biological system and environmental information.

A key concept in dynamical systems theory is that of constraints (Ko, Challis, & Newell, 2003; Newell & McDonald, 1994). Constraints arise from various sources within the human body itself (i.e., biological constraints), from the task (goals, rules, structure), and from the environment (i.e., contextual information/feedback received through perceptual/sensory channels, including physical and social elements). Research by Newell and Slifkin (1998) confirmed that these three constraint types influence the learning process simultaneously. They found that constraints for each skill are manifest in different ways in different individuals, even among performance experts, adding complexity to teaching and learning complex motor tasks.

Take, as an example, learning the skill of overarm throwing. There are a number of environmental factors other than the throwing pattern itself playing key roles in the skill acquisition process, such as object size and weight, playing field size and goal dimensions, and game rules that can facilitate or constrain skilled (and accurate) throwing. Throwing, Roberton (1982) argued, also is preliminary to performing the catching skill in both isolated and more environmentally complex game situations. Research by Breslin and his colleagues (2009) examined changes in the glenohumeral horizontal abduction angle (a relative angle greater than 180° between the humerus and the trunk) in novice throwers, resulting from throwing different weighted objects. The researchers filmed 15 novice preschool-age children (M = 4.69 yrs.; 7 girls) throwing baseballs and softballs, each with a different mass, twice each.

Results indicated that novice throwers failed to achieve change in the glenohumeral horizontal abduction angle as a result of adjustments to changes in object weight. This is consistent with teachers’ observations of novice throwers who are inclined to “push” the ball with a simultaneous motion “rather than the sequential whip like motion typically demonstrated with a temporal and spatial lag in the forward movement of the humerus” typically found in skilled baseball pitchers (Breslin et al., 2009, p. 377). Additionally, high standard deviations in the angle measurements indicated that these children had not yet developed a consistent throwing pattern. Thus, they demonstrated inconsistencies in throwing pattern attributable to ball size, grip size, and strength when attempting to perform an overarm throw under novel task constraints.

Findings from previous research (Southland, 1998) conducted with mature throwers found that throwing motion changes occurring with the addition of external mass (heavier objects) cannot be generalized to novice throwers. Research with novice performers is subject to large performance variability. Novice throwers, such as those in this research, demonstrate an “extremely limited glenohumeral horizontal abduction angle suggesting that the cocking phase of the throw was not developed enough to generate the momentum required for increased inertia of the hand to draw the arm back” (Breslin et al., 2009, p. 378).

These findings provide additional support for the developmental nature of the overarm throwing pattern. It is likely that in most physical education classes, heterogeneity
of students’ throwing patterns requires teachers to make significant adaptations within particular throwing tasks. Novices assessed on throwing tasks with different size and weight objects that require mature throwing patterns are unlikely to perform the task successfully. When children “lack the mechanical capability to exploit the inherent inertial properties of balls with increased size and mass,” they are likely to fail regardless of the quality and nature of instruction and teacher feedback (Breslen et al., 2009, p. 378).

Understanding this variability explains, in part, why children learn the same skill in different ways and at different rates. Dynamical systems theory also describes how and why context-dependent skills taught within small-sided games, for example, may work to facilitate skill learning and more advanced game play in young learners (Kirk & Kinchin, 2003). MacPhail, Kirk, and Griffin (2008), building on the work of Nevett, Rovegno, Babiarz, and McCaughtry (2001), studied learning associated with throwing catchable passes in territorial games (games with a goal at each end of the field or court; attackers invade the defenders’ territory to score; e.g., soccer, basketball). The term catchable pass, in this case, is an environmental constraint for the overarm throwing skill. To successfully catch the thrown object, both the thrower and the catcher must respond to the complex, dynamic environment by adjusting their movements in response to the other, while the catcher must also adjust to the object’s flight. Additionally, when one or more defenders are involved, as in most authentic territorial games and sports, the complexity of the task increases exponentially.

In the MacPhail et al. (2008) research, elementary school students participated in a six-week long learning unit. Data consisted of video-recorded learning behaviors and semi-structured student interviews. Using the Game Performance Assessment Instrument (Griffin et al., 1997), the researchers analyzed the data in terms of decisions made, skills executed, on-ball support movements, and defensive moves. They concluded that learning to throw accurately is constrained by the thrower’s and the catcher’s understanding of catching. Learning to execute throwing skills in a complex learning environment is coupled with both learning to catch and the understanding of catching in complex game environments.

In summary, these three major frameworks have been instrumental in explaining motor skill learning and performance (or transfer) in complex game and sport environments. The frameworks focus primarily on the neural-biological mechanism of the skill learning process. It was not until the advent of dynamical systems theory, however, that motor skill learning was studied in context. Empirical evidence strongly supports two conclusions. First, learning in the psychomotor domain requires high level cognitive functioning with a strong declarative knowledge of skill execution and performance. Second, learning motor skills requires the learner to proceduralize declarative knowledge within the context in which the skills are performed. It is likely that skills are not pre-learned or pre-programmed in isolated skill practice but emerge to address and overcome contextual constraints. Skill performances within complex game situations rely on the individual’s richness of knowledge and skill repertoire developed through extensive, skill-level appropriate, game-like practice opportunities.

**CURRENT TRENDS AND ISSUES: LEARNING TO MAKE TACTICAL DECISIONS IN COMPLEX GAMES**

Physical education scholars, teachers, and athletic coaches value both the learning of physical skills and the application or transfer of those skills effectively into complex
Learning Motor Skill

165

game and sport situations. Intricate, swiftly changing social situations, such as those found in team games, challenge learners to recognize complex patterns inherent in offensive and defensive tactics. Critical to team success is each learner’s ability to anticipate the need to create and attack space or limit space and defend game territory. In so doing, they must both think and move temporally and spatially—at the right time, to the right place—and then effectively perform the right skill.

Cognitive knowledge of skill, sport, and fitness concepts and the social and cognitive processes that enhance or constrain individual and team skills and tactics are relevant in most physical education curricula. Research in physical education examining student learning as the cognitive understanding of what, how, and when to perform a skill has contributed a critical element to elaborate dynamical systems theories of motor skill learning. In this section, we discuss research examining student motor skill learning in complex social situations. In so doing, we summarize physical education research conducted within the Games for Understanding curriculum models (Gréhaigne, Wallian, & Godbout, 2005; Griffin & Butler, 2005).

Advocates of decision-making games curricula (e.g., Gréhaigne et al., 2005) view learning as an active, social process. They examine and value the relevance of prior knowledge in learning and utilize the social nature of games to enhance knowledge construction (Griffin & Butler, 2005). How students learn to perform skills within complex game environments is of particular importance in physical education, where a significant allocation of instructional time is devoted to team games at elementary, middle, and high school levels. Students are required to apply or transfer isolated motor skills (e.g., throwing, kicking, catching, and hitting) into the multifaceted, quickly evolving contexts of team games. Few other educational environments require learners to master their own cognitive and physical performances, while simultaneously countering the decisions and skills of a crafty opponent.

Currently, researchers are examining learners’ cognitive engagement as they learn game strategies and tactics within these models. Because of the cognitive complexity involved in successful performance, research designs often employ game scenarios to capture student learning. Blomqvist, Vänttinen, and Luhtanen (2005), for example, used a video-based test to evaluate 14- to 15-year-old male students’ understanding of soccer tactics. The video portrayed skillful boys playing a modified (3 vs. 3) soccer game. The video included 17 game sequences (9 offensive and 8 defensive) selected by expert coaches from 47 filmed sequences. Each sequence included a lead up play prior to the game situation to be evaluated, followed by the presentation of a still frame on which arrows were imposed representing three play, pass, or movement response options. Learners first decided what to do and then had 45 seconds to select two relevant arguments from a list of eight written arguments to explain their decision.

Blomqvist and her colleagues (2005) found that students made significantly more decisions related to the offensive tactic of maintaining possession of the ball than in other offensive or defensive situations. Learners scored on average 71% correct decisions in the game understanding video test in which they responded to offensive game situations (74% correct) and defensive situations (67% correct). Again, this research was conducted in an experimental situation and not within the complexity of a physical education class. The extent to which these tactical decision-making skills transfer to physical education lessons is not known.

Physical educators strive to teach children to apply isolated motor skills effectively in game situations (French, Werner, Taylor, Hussey, & Jones, 1996). When teaching children, instructors simplify the environment and teach using game sequences that
represent key parts of the game, such as maintaining possession of the ball, scoring, and defending. Nevett et al. (2001), for example, focused on passing and catching as key components of maintaining possession strategies that place throwing/catching skills within a social context. Nevett and his colleagues conducted research to describe changes in fourth-grade students’ use of basic tactics as a result of a 12-week unit on game tactics. Participants played a game of 3 vs. 3 aerial basketball before and after instruction. The object of the territorial game was to score goals by passing a ball to a teammate standing within one of two hoops in the attacking end. Additionally, they were required to defend these goals from attack by the opposing team. Hoops were placed so that players could attack the hoops from all directions. They could advance the ball only by aerial passing; traveling with and stealing the ball were not permitted. Each 8-minute game was videotaped from the school roof to capture the overhead view of the playing area. The same teams were kept for the pre- and post-game situation, and players wore colored vests with numbers to facilitate identification.

The researchers used two coding instruments to examine decision making and motor skill execution. The first instrument recorded children’s passing decisions and passing-skill execution, while the second captured cutting or off the ball actions and catching-skill execution. Children’s decision-making skills and actions were based on the overt behaviors they displayed during the games. Additionally, passing decisions and passing-skill-execution coding further evaluated the passer’s actions. The researchers coded and evaluated the following actions: (a) passing decisions judged good or poor, (b) the type of good or poor decision (8 types considered), (c) the length of the pass (appropriate, too short, too far), and (d) the quality of the pass (7 levels). The second instrument was used to evaluate receivers’ cutting actions and catching motor skill execution. Cutting/catching-related activities were coded into five categories: (a) cutting actions judged as good or poor, (b) the type of good or poor action (9 types), (c) the direction of the movement made to receive the pass (5 directions), (d) the distance from the passer to receiver (appropriate, too short, too long), and (e) catching ability (5 levels). Data were analyzed as the percentage of each participant’s total number of passing trials with good passing decisions and cutting actions. Because change in passing and cutting was the research focus, data were analyzed using two separate Gender × Skill Level × Test ANOVAs with repeated measures on the last factor.

Results indicated that children increased the number of effective passing and cutting decisions and quality of passes during the game tactics unit as reflected by the increase in the number of successful catches from pre to posttest. There were no differences by gender or skill level. Specifically, the number of appropriate lead passes, held ball decisions, and successful catches increased significantly, reflecting improvement in receivers’ number and quality of cuts. The results from this study indicated that effective passing and cutting tactics can be learned by fourth graders in a physical education school-based setting when simple tactics, such as throwing lead passes, are the focus of instruction. Catching a pass requires children to move into an open space rather than standing still and calling for the pass. Many territorial games require the use of effective lead passes and successful catches to advance the ball into opponent’s territory.

Rovegno, Nevitt, Brock, and Babiarz (2001) provided clear descriptions of fourth-grade children’s developmental patterns when attempting to play throwing and catching games. The practical implications of this research are that teachers can readily observe these behaviors and teach directly to counter children’s ineffective tactics. Specifically, Rovegno et al. (2001) found that fourth-grade receivers tended to move or cut too slowly into a space using a curved (i.e., a banana cut) rather than a straight
pathway. Receivers at this developmental level also tended to cut behind the defender and to reverse direction just as the ball was thrown or just as the receiver was about to evade the defender. Not only did the receiver not catch the ball, but these ineffective cutting patterns also were detrimental to the passer’s learning of effective throwing practices. In this situation, the passer was reluctant to attempt effective passing strategies, such as leading the receiver and passing as the receiver was moving into an open space, and thus was less likely to throw a pass that the receiver could catch. Instead of passing ahead of the catcher’s projected pathway (lead pass), throwers were more likely to send the pass behind the receiver, directly to the defender, or to the place where the receiver had been standing prior to cutting to receive the ball.

As a result of this analysis, Rovegno and her colleagues (2001) provided specific instructional tasks and teaching cues to assist fourth-grade receivers learn to use quick, straight cuts into an open space, thus reinforcing the passer’s attempts to throw lead passes into open spaces, learning to release the ball before the receiver reached the space. Although this simultaneous emphasis on the individual, task, and environment increases the complexity of the learning task, the authentic nature of the catchable pass context increases learners’ understanding of temporal and spatial task dimensions. The situated nature of the catchable passing task enhances learners’ understandings not only of how to perform a throw and a catch, but also when and where to pass, increasing students’ opportunities for success in complex game situations (Rink, 2014).

CURRENT TRENDS AND ISSUES: SKILL LEARNING AND COGNITIVE PROCESSES

An emerging paradigm in studying motor skill acquisition takes an ecological perspective by focusing on the interaction of the general learning environment and learner thought processes. A salient tenet from this perspective is the notion that all human physical actions are guided and controlled by goals (Prinz, Beisert, & Herwig, 2013). The cognitive processes associated with executing actions are centered on movers’ goal awareness and recognition within the constraints of physical and social environments.

Several factors influence learners’ motor skill goal construction. Most salient of these include learners’ (a) conceptions of physical competence, (b) perception of social norms or preferences, and (c) self-controlled feedback mechanisms for performance. These factors are cognitive in nature because they are products of the learner’s thoughts prior to and during learning specific skills.

Competence Conception

When learning in the psychomotor domain, children tend to demonstrate patterns in competence conceptions similar to those in classrooms as described by Dweck (1999). They either hold an entity or an incremental belief about physical competence (Li & Lee, 2004). Children who believe physical skill development is pre-determined by heredity espouse an entity perspective, denying that investing energy in practice will lead to significant improvement. Conversely, those who believe in the incremental perspective readily engage in skill practice, assuming that skills develop in small steps with effort and persistence.

Li, Lee, and Solmon (2008) conducted a study with the purpose of understanding the impact of competence conceptions on learning gross motor skills. In the study, the researchers adopted a novel gross motor skill as the learning task to control for
Catherine D. Ennis and Ang Chen

possible impact from pre-determined competence conception. They then manipulated the learning environment to convince learners they were either born with the skill to perform the task (the entity conception condition) or they had learned or could learn the required skill (the incremental conception condition). Additionally, they used video assisted instruction to ensure that learners in both conditions had the same type and level of information necessary for the tasks. College students were randomly assigned either to the entity or incremental competence conception conditions and taught a novel baton flip and catch task (Li et al., 2008, p. 53). The variables measured in the study were learners’ competence conception about the skill, intrinsic motivation, perception of skill difficulty, persistence, and skill performance.

The ANOVA analysis revealed that the entity condition was more successful at convincing learners in their born-ability to perform the task than the incremental condition was at convincing learners in the value of effort in successful task performance. Although the researchers did not find a significant difference in skill performance based on the entire or incremental conditions, they did report an interaction impact of the incremental condition and intrinsic motivation on effort. Additionally, the learners in the incremental condition exhibited strong intrinsic motivation, persisting longer in practice than those in the entity condition.

The study echoed results found in similar studies of perceived competence (e.g., Belcher, Lee, Solmon, & Harrison, 2003). Different competence conceptions are a factor in impacting the learning processes. The evidence suggests that the effect of perceived competence on skill performance measures can be mediated by intrinsic motivation. Collectively, the impact of perceived competence on persistence, a precursor of improvement in performance, can be significant.

SOCIAL NORM OR PREFERENCE IN SKILL PERFORMANCE AND PERCEIVED COMPETENCE

One social norm or preference in the psychomotor domain is the conception of gender-appropriateness. Individuals’ beliefs about gender appropriateness of a sport or a skill has been central to motor skill learning (Lirgg, 1991). Children (Lee, Fredenburg, Belcher, & Cleveland, 1999), as well as adults (Lirgg, George, Chase, & Ferguson, 1996), often perceive and categorize sports, physical activities, and skills along gender appropriateness dimensions. Gender-centered beliefs often determine and limit one’s perceived physical competence and effort in learning skills. This is particularly true for girls’ sports interest and learning and boys’ interest and willingness to learn Olympic gymnastics, figure skating, and dance-related activities.

Belcher and his colleagues (2003) manipulated gender appropriateness perceptions in learning the ice hockey wrist shot skill. Female college students were divided into two groups based on their strongly held beliefs that ice hockey was either a male-oriented sport or a gender-neutral sport. Both groups were taught the hockey wrist-shot skill. Videotaped male or female models were shown to the learners to reinforce their original conceptions of gender-appropriateness. The learners’ competence conceptions (entity vs. incremental) were measured along with effort and skill performance. Results showed that learners’ expectations for success in skill acquisition were divided along gender-appropriate lines. Learners with gender-neutral beliefs estimated and expected greater learning success than those with gender-appropriate beliefs. Gender-neutral performers also outperformed their counterparts in skill execution. Other researchers (e.g., Clifton & Gill, 1994) found that gender-appropriateness impacted both male
Learning Motor Skill

and female learners’ skill acquisition and performance by mediating their self-efficacy beliefs. Males reported stronger confidence in “male appropriate” masculine activities, while females reported stronger confidence in “female appropriate” feminine activities.

There is emerging evidence, however, that “gender-appropriate” thought process may be disrupted when learning tasks with strong situational interest. Shen, Chen, Tolley, and Scrabis (2003) studied situational interest effects on boys and girls in dance, a “gender-preferred” female activity, controlling for personal interest. The researchers found that in a situationally interesting environment boys and girls were equally engaged (and physically active) in the psychomotor learning processes as measured by heart rate. Although girls outperformed boys on skill and knowledge tests, they both considered the learning environment situationally interesting and engaging.

These findings may lend support to the hypothesis that cognitive processes involved in learning gross motor skills may be mediated by variables beyond the immediate instructional parameters, such as task construction and skill feedback. Cognitive processes encompass a large spectrum of dispositional thoughts and beliefs that may be as diverse as the learners’ life experiences brought to the gymnasium. Although findings across different studies are not consistent, cognitive processes may not function within the same learning process mechanisms required for motor skill learning and mastery. A plausible hypothesis might be that thought processes originate as mental dispositions and work with perceptual components involved in skill acquisition, such as self-imposed evaluation and feedback.

Self-Imposed Evaluation and Feedback

In a previously described study, Belcher et al. (2003) manipulated the learning environment by providing “gender-appropriate” feedback to reinforce learners’ original “gender-appropriate” belief, resulting in a gendered difference in skill performance outcome. Teacher-provided feedback included both “gender-appropriate” and performance-related information. By using this approach, the researchers aligned their design with the hypothesis that effective feedback should emphasize performance-related information, allowing learners to process relevant performance information in terms of goal actions. Researchers hypothesize that cognitive processes are grounded in the interaction of the human sensory system, action system, physical environment, and social environment. If this is the case, the outcome of the interaction should lead to a grounded cognitive process relevant for the motor action (Kiefer & Barsalou, 2013). During this process, learners’ self-controlled feedback is central to effective learning because it serves as a self-regulated learning strategy permitting the learner to choose when to receive different feedback types (Chiviacowsky & Wulf, 2005).

A series of studies done by Wulf and her colleagues illustrates the importance of using contextually relevant learning feedback to enhance skill acquisition. Coupling feedback with the social-cognitive theory (e.g., self-regulated learning strategies), these researchers were able to clarify advantages or disadvantages of self-controlled feedback in learning motor skills. For example, teaching learners to self-control for when to receive feedback benefited learners by reducing timing error in learning and increasing skill transfer (Chiviacowsky & Wulf, 2005). Further, Wulf, Raupach, and Pfeiffer (2005) found that when learning a complex skill (i.e., basketball jump-shot) through either self-controlled observation or scheduled observation, the learners in the self-controlled observation condition were better able to retain the skill (although not the performance) than those in the scheduled condition. However, when the motor skill
involved the use of a device (e.g., using ski poles to assist learning to ski), self-control centered learning strategies did not benefit learning directly as measured in performance (Wulf, Clause, Shea, & Whitacre, 2001). Because the tasks used in these studies ranged from lab-based tasks such as tapping for accuracy (Chiviacowsky & Wulf, 2005) to a complex task (basketball jump shot; Wulf et al., 2005), it is difficult to reach a definitive conclusion about self-controlled learning effects. Researchers, nevertheless, have begun to demonstrate the possibility that motor skill learners may benefit from self-controlled feedback mechanisms that allow learners to consider contextual relevance and timing of the information received during motor skill acquisition.

Cognitive processes are no doubt important components in motor skill acquisition. During the learning process, learners receive and process not only motor-relevant information from performance, but also information about the physical and social context in which the motor skill is performed. The latter information includes information about competence, social relevance, and control. Although research examining these variables in association with motor skill learning is progressing, at the present time it is not yet possible to draw conclusions about the association between these variables and motor skill development.

FUTURE DIRECTIONS

Although the body of research in learner cognition in physical education has been growing, research examining learners’ beliefs and naïve conceptions that facilitate or constrain learning is just emerging as an area of study in physical education. Historically, physical educators have been aware of children’s difficulties in learning to play complex games. Even preservice teachers are quick to comment on the extensive amount of instructional time required for students to learn to play even simple games effectively. For example, when first learning to play territorial games, novices typically run directly to the ball in an attempt to gain possession. This naïve conception results in novice players congregating in a small space around the ball as they attempt to catch or kick the ball toward the goal. Griffin, Dodds, Placek, and Tremino (2001) described this as “bunching” and discussed learners’ perceptions of bunching in research with middle-school students.

Game tactic learning provides a ripe area of study for researchers interested in conceptual change. Griffin et al. (2001), for example, conducted ethnographic research to examine sixth-grade physical education students’ understanding of soccer tactics. They used focused, structured interviews in which learners responded to seven basic tactical problems. During the interview, learners moved game pieces representing players on a soccer field game board and verbalized what those players should do in each situation and their rationale for each decision.

Researchers classified students’ responses into four conceptual models or levels. A level 1 response described skills in isolation without identifying connections among skills, while responses categorized as level 2 described skills and gave reasons for using the skill in a game to score goals. Level 3 categorizations provided reasons for using skills in a game and possible consequences for particular actions. It was not until level 4, however, that learners could describe coherent sequences of actions, give reasons for those actions, and explain tactical options within condition-action (if-then) statements. As in the Blomqvist et al. (2005) study, middle-school learners could solve offensive tactical problems more accurately than defensive problems. The majority of these learners were categorized at level 2 (41%) and level 3 (32%). Girls’ responses
reflected levels 1–3, while boys’ responses fit levels 2–4. None of the girls’ responses was categorized at level 4. Boys reported more previous formal and informal soccer experiences than girls. The researchers concluded that soccer experience was the most influential variable in acquiring and transferring soccer tactical knowledge. Girls’ lack of out-of-school experiences in soccer limited their conceptualizations of tactical play.

This research reflects limitations inherent in many physical education curricula and state and school district learning expectations. Although researchers collected data on students’ authority sources, they were not able to compare student knowledge with objective knowledge standards such as found in detailed state or school district curricula or textbooks. Currently, few school districts provide physical education textbooks or other written material to assist teachers to establish detailed and standardized learning objectives and assessment criteria to structure the teaching-learning process. Most physical education teachers create curricula and design lessons themselves, becoming familiar with students’ knowledge and misconceptions as they search for reasons why students perform in ways counter to teacher instructions and or resist correction or change.

Likewise, physical education teachers may be unaware of grade-appropriate skills, tactics, or other outcomes because these have not been established or validated using large samples, and student performance has not been routinely measured. Without objective sources, it is more difficult to identify naïve theories or models of student conceptions. Griffin et al. (2001) also did not attempt to capture students’ epistemic and ontological beliefs and theories about soccer knowledge, further limiting understanding of learners’ naïve conceptions. Increased understanding of conceptual change processes in children’s physical education concept and skill learning can lead to more effective resources for enhanced teacher training and improved curricular and instructional materials, permitting teachers to target naïve, counter-intuitive, and resistant naïve conceptions or misconceptions (Vosnaidou & Brewer, 1992). Future research examining tasks leading to conceptual change associated with skill, sport, and fitness content can result in improved instruction and enhanced efforts to address students’ naïve conceptions.

Researchers have begun to link learners’ cognitive processes associated with competence and social norm issues to motor skills learning, providing greater insights into the building blocks of coherent performance. Limited research findings to date suggest that skill learning benefits from an incremental conception of physical competence and a socially neutral view of the skills and games to be learned, especially when the social view is related to gender-appropriateness. Because learners “own” their thoughts and thought processes and because thoughts and thought processes are mediated by socially constructed conceptions of competence and preferences, teaching learners to control critical factors within the learning process, such as when to receive what types of feedback, may benefit learning complex motor skills and game tactics.

In conclusion, motor skill and tactical learning is a complex and time-consuming process. When the learning focus is on application or transfer of skills and tactics within increasingly more complex game environments in physical education settings, it is likely that the instructional time required to learn to perform effectively exceeds the instructional time allocated to K–12 physical education in most public schools. Additionally, because students are not grouped by prior knowledge, experience, or ability when assigned to physical education, the vast diversity of student skill and tactical prior knowledge and performance ability in most physical education classes makes each lesson its own unique expert-novice design. Thus, it is likely that most effective
game players learn to become skillful outside of physical education in athletic and recreational settings where practice time is extensive, players are grouped by skill level (teams, leagues), and the coach is an expert teacher who focuses on skills and tactical game play within a particular sport (Ennis, 2006).

Physical educators are fortunate, however, to be able to draw on an array of evidence-based research studies examining motor skill and tactical learning. These studies have been conducted by scholars from a variety of research perspectives examining a number of critical variables in laboratory and instructional settings. Nevertheless, understanding and interpreting the findings for application in physical education is a challenge even for physical educators with advanced expertise. Continuing efforts to understand motor skill learning in physical education and increasingly more complex sport environments should provide additional opportunities for enhanced instruction and student learning.

REFERENCES


Krigolson, O. E., & Tremblay, L. (2009). The amount of practice really matters: Specificity of practice may be valid only after sufficient practice. Research Quarterly for Exercise and Sport, 80, 197–204.


