HOP.SKIP.JUMP.GAMES

The design, development, deployment and evaluation of video games to support locomotor acquisition in a classroom setting

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DECLARATION

I declare that this thesis has not been submitted as an exercise for a degree at this or any other university and it is entirely my own work.

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ABSTRACT

Sedentary video gameplay is typically described as a contributing factor to poor locomotor skills (hop, skip and jump etc.) observed in the modern day child. Further, poor locomotor skills are a significant predictor of problems elsewhere including health, speech and language, behaviour and reading fluency. Conversely, with the emergence of 3D sensor interfaces (e.g. Kinect), video games now support full body gross motor simulated interactivity. This offers an intriguing opportunity to transform a potential barrier to locomotor acquisition into a veritable training ground.

This thesis is initially concerned with the design of a theoretically informed and 'principled' framework (entitled **PaCMAn**: Principles and Conditions for Motor Acquisition) which can be utilised to underpin video games for locomotor acquisition for use in the classroom setting. Following this, a series of adaptable games are developed to facilitate instant adaption of gaming features by a *human adaptive component*; the teacher. The adaptive nature of these games allows the teacher to negotiate currently existing 3D sensor limitations by adapting parameters of gameplay 'on the fly' in line with individual user needs. The teacher is also expected to deliver additional parts of the framework that the game/system cannot.

Specific details relating to the role of the teacher, in terms of the deployment process, were evaluated during an initial period of action research carried out in the classroom setting. This resulted in the articulation of A *Teacher Adaption and Deployment Guide*. A second period of action research focused on the effectiveness of videogames for locomotor acquisition in the classroom; both from the point of view of the teacher (i.e. could teachers do all of the things asked of them in the deployment guide?) and from the point of view of the learner (i.e. did an extended period of gameplay lead to improved locomotor skills?).

Quantitative findings indicate that the games outlined in this thesis supported significant improvements in user locomotor skills. Additionally, qualitative findings indicate that teachers were not only capable of deploying these games effectively but were also empowered by the meaningful role they had to play in the delivery process. Ergo, video games present as a useful platform capable of supporting and enhancing both the teaching and learning of locomotor skills in the classroom setting.

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1 INTRODUCTION

1.1 MOTIVATION

Gross motor development refers to the acquisition and improvement of athletic abilities involving large muscles in the arms and legs. These abilities are divided into two subsets; (i) *locomotor skills* (run, hop, skip, jump, slide, etc.) and (ii) *object control skills* (kick, bounce, throw, catch, bat, etc.). Locomotor skills typically emerge in predictable stages between the ages of 3 and 6 years. They are the building blocks for successful participation in physical activities (Payne & Isaacs, 2011). Thus, poor locomotor acquisition is a significant predictor of non-participation in sport which increases the risk of obesity, low self-esteem, low social confidence and mental health problems in later life (Harter, 1981; Doganis & Theodorakis, 1995; Cairney et al. 2005). Recent studies outline significant links between poor locomotor acquisition and poor performance elsewhere including; speech and language (Olander, 2010), behaviour (Brossard-Racine et al., 2011) and health (Sander & Kidman, 1998; Pica, 2010). Furthermore, recent studies point towards a cause and effect relationship between locomotor acquisition and cognitive development (see: Van Der Fels et al., 2015; Anderson et al., 2014, Vuijk et al., 2011; Westendorp et al., 2014). Findings indicate that children in possession of poor locomotor skills are also likely to experience difficulties with cognitive tasks particularly reading and mathematics. Accordingly, well developed locomotor skills present as an important part of childhood development.

For previous generations, locomotor skills emerged through maturation owing to the fact that self-generated play habits were effective (Akbari et al. 2009). G*ames of the past* including *Hop Scotch, Hand Skipping* and *Leap Frog* supported acquisition of a hop, skip and jump respectively. Conversely, the modern child demonstrates significantly lower levels of locomotor skills (Lam, 2011; Mc Phillips and Sheehy, 2004). In Ireland, 89% of adolescents fail to demonstrate proficiency of locomotor skills previously mastered by 6 year olds (O'Brien et al., 2014). This regression is largely attributed to an increased sedentary lifestyle and new forms of play including video games (Lam, 2011). Indeed, the majority of children worldwide spend at least 3 hours a day online, or playing video games (Guthol et al., 2010).

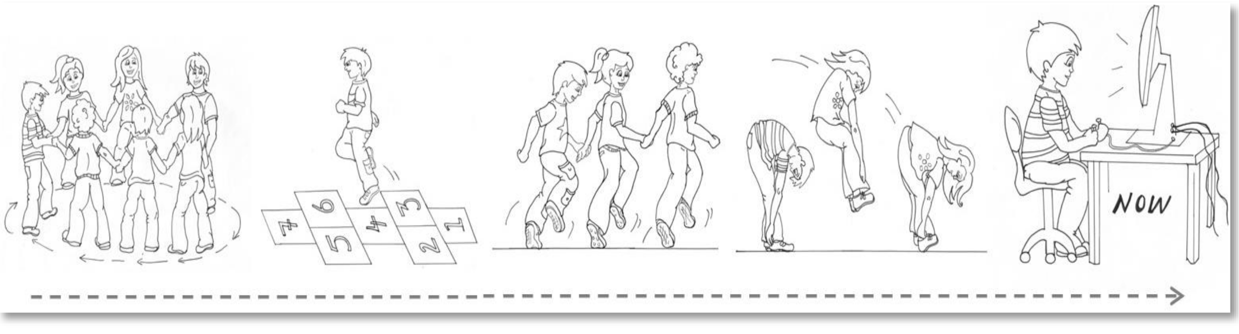


FIGURE 1.1 GAMES OF THE PAST FACILITATING LOCOMOTOR ACQUISITION COMPARED TO CURRENT PLAY 'RING A ROSIE' SLIDING, 'HOP SCOTCH' HOPPING, 'HAND SKIPPING' SKIPPING, 'LEAP FROG' JUMPING

The sedentary nature of video gameplay is typically described as having a negative and dynamic impact on both physical fitness and locomotor acquisition (Straker et al., 2011).

However, with the emergence of 3D sensor interfaces (PrimeSense, Kinect etc.), game control has shifted from sedentary finger tapping (joypad, game controller) towards full body simulated interactivity (figure 1.2). A new genre of *exergames* has emerged, typically designed for recreational purposes but also with the intention of developing user fitness levels (Wii Fit, Kinect Sports etc.). Interestingly, some exergames call upon the user to run, hop and jump in order to *control* a game character and achieve success. Thus, suggesting a potential platform for locomotor training and acquisition.

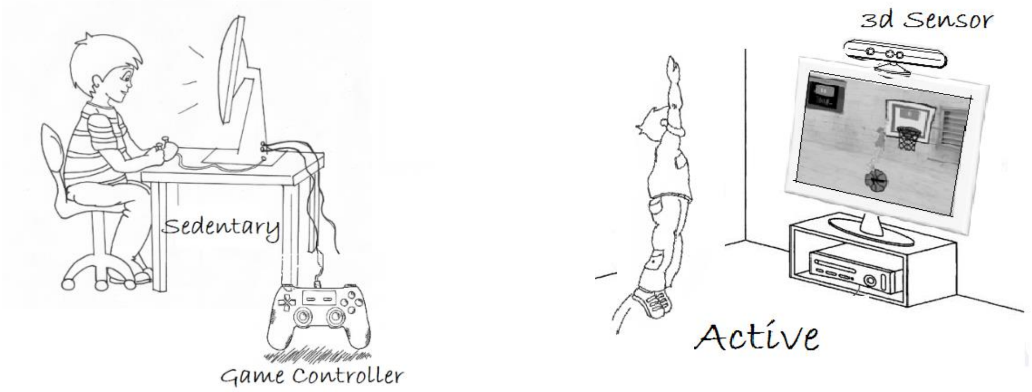


FIGURE 1.2 A SHIFT IN GAME CONTROLLERS AND CONTROL OUTPUTS: SEDENTARY TO ACTIVE

Despite advances in sensor technology, it is rare to encounter video games that are purposely designed to support motor training and acquisition (Wiemeyer & Schnieder, 2012). Furthermore, there are no popular exergames marketed towards *locomotor* training and acquisition. We know that games intended to target specific skills should be underpinned by pedagogical theories (Kebritchi et al., 2010) and that game design should be informed by a clear understanding of how people learn (Lainema & Saarinen, 2010). Despite this, most exergames available to us present as 'one size' fits all, i.e. gameplay does not adapt to meet individual user needs/characteristics (Hardy et al., 2015). For example, the height of a target or length of play determines the height a user is expected to jump and number of jumps they are expected to perform. These parameters or *conditions* of gameplay should not exceed user capabilities and yet, most games do not differentiate from one user to another. In addition, 3D sensors have several limitations including poor accuracy detecting bi-lateral and/or fast movements using the lower limbs. This allows for 'cheated' user outputs during gameplay (Gao & Mandyk, 2012). That is, a locomotor skill can be reduced to a basic arm lift if the user moves close to the sensor. Thus, video games in their current state cannot support locomotor acquisition owing to a lack of purposeful design, a lack of theoretical underpinning and a series of technical limitations.

In recent years, there has been a significant increase in the amount of locomotor training programs made available to schools (Gallahue et al., 2012; Houwen et al., 2014). Researchers note however, that a majority of these programs are not informed by *motor learning theory.* Conversely, there is little empirical evidence to support their worth (Gallahue et al., 2012). In relation to motor learning theory, there appears to be a disconnected understanding amongst researchers as to what constitutes the most effective 'ingredients' or *principles* for locomotor training and acquisition. Indeed, principles are typically examined in small clusters from one study to another and articulated in a variety of ways across the literature. This makes the most effective principles for locomotor acquisition difficult to track and record. Consequently, there is a need to conduct an *inductive analysis* on empirically supported studies that refer to effective gross motor training and acquisition regimes. This inductive analysis could (i) condense a large and varied set of principles into a summary or list format (ii) establish patterns, links and effectiveness (iii) deploy findings to inform a theoretical and 'principled' framework. Such a framework could then be utilised to underpin the design, development and deployment of video games for locomotor training and acquisition.

Despite a number of previously outlined shortcomings (lack of purposeful design, 3D sensor limitations etc.), recent studies provide empirical evidence to support the use of 'popular' (typically recreational) exergames for the rehabilitation of basic motor skills (e.g. moving hand to mouth) in stroke patients (Shiratuddin et al., 2012; Levac, 2015). However, these studies often understate the importance of the clinician's (human) role in terms of effective game deployment. For example, the clinician is typically expected to choose the appropriate game and demonstrate the desired movement response for the patient. He/she is also expected to monitor movement execution and provide expert feedback/instruction. The clinician terminates gameplay when the patient is fatigued or frustrated, essentially 'adapting' the length of the play to suit individual capabilities. In this way, the clinician could be described as a *human adaptive component*; negotiating design and sensor limitations by adapting parameters of gameplay and delivering additional expertise/information to the user that the game does not. This means the human (in this case the clinician) has a potentially significant role to play when it comes to the effective deployment of video games for motor training and acquisition.

In order to facilitate this type of human/game adaptive process, the human should be enabled to instantly (re)configure parameters of gameplay with little more than a click, slide or drag of a button. However, Webster & Celik (2014) remind us that commercial/popular exergames are limited in their use for motor rehabilitation purposes by virtue of the fact that they are rarely adaptable. To that end, several studies refer to the fact that clinicians often resort to utilising the 'power off' button in order adapt the length of gameplay in line with patient needs (Shiratuddin et al., 2012; Levac, 2015). This type of crude adaption is hardly ideal and alternative adaption processes are demonstrated elsewhere. For example, *ErgoActive* mini games for health (Göbel et al., 2010) offer access to a 'property editor' allowing for the instant adaption of several parameters (including length of play) with relative ease. Adaptable games afford the human (clinician, practitioner, teacher etc.) an opportunity to negotiate technical limitations and deliver motor learning principles that the system cannot thus, offering them a powerful role in the deployment process. However, with this power comes responsibility. That is, the effect that gameplay has on motor training and acquisition may well depend on the teacher's ability to adapt games appropriately in line with individual user needs.

In order to support effective deployment, the human must know what is expected of them. Essentially, finer details relating to the overall deployment process require clarification. Indeed, several authors note that, in general, teachers and clinicians lack knowledge and understanding around how best to deploy exergames for motor training purposes (Vernadakis et al., 2015; Levac et al., 2015). Thus, humans require a consistent rubric or *guide*, to support a consistent and effective deployment process.

Taking all of the previous into consideration, video games for locomotor acquisition may become a reality under the following circumstances. First, a series of games to target locomotor skills training should be underpinned by a principled **design** framework. Second, a 'human adaptive component', the teacher, should be utilised to negotiate 3D sensor limitations and facilitate parts of the framework that the games cannot. Accordingly, game **development** should be mindful to include adaptable design features and thus, gaming parameters. This adaption should be carried out by a human adaptive component (teacher) who is supported during this **deployment** process through the use of an explicit *guide* or manual that systematically outlines their role.

With all of this in place, it is then essential to carry out an **evaluation** into the effectiveness of these games from *two* perspectives. First, from the point of view of the teacher, i.e. are they capable of doing all of the things laid out for them by the guide/manual? Then from the point of view of the learner, i.e. does video gameplay lead to improved locomotor acquisition? A systematic research approach is required to explore all of the previous, the design, development, deployment and evaluation of video games for locomotor acquisition in the classroom.

1.2 RESEARCH APPROACH

This thesis unfolded during and following a period of **action research** that took place predominantly within a classroom setting. This afforded a unique cycle of investigation into the *design, development, deployment* and *evaluation* of video games for locomotor acquisition.

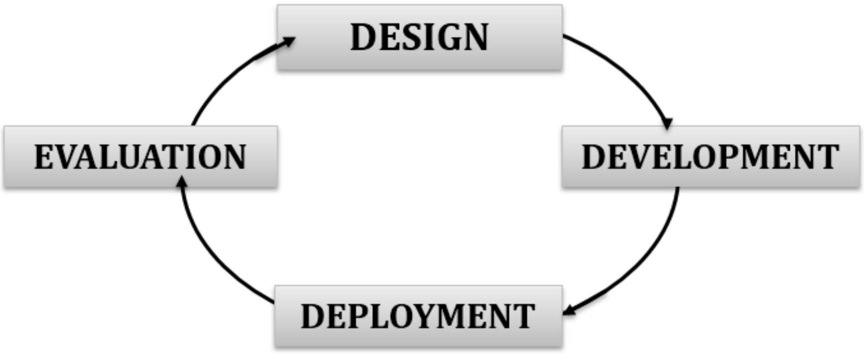


FIGURE 1.3 ACTION RESEARCH CYCLE 1

In recent years, game designers have borrowed from research in an attempt to develop games that benefit teaching and learning. This has resulted in a number of *research to practice* hubs (including 'games + learning + society') that form collaborations between game developers and researchers. However, there is still a significant lack of consideration for the teacher and the constructs of the classroom (Chmiel & Mazur, 2012; Herro, 2016). Accordingly, the design of video games for locomotor acquisition in this study benefitted greatly from my 'day job' as a primary school teacher, which placed me in a unique position to research, design and develop for a cohort (children aged 5-7) with whom I had continuous access and extensive experience. This position also afforded me access to a cohort of teachers, my colleagues, who provided additional insight into the reality of deploying video games for locomotor acquisition in the classroom setting.

Design: The research began with the construction of a *principled design framework* used to underpin design, development and deployment of video games for locomotor acquisition. An analysis of exergames already on the market was conducted to identify 'design features' that would potentially correlate with principles in the framework. It was believed that individual user needs could be supported by adapting these design features and thus, parameters of gameplay. However, owing to technical limitations including 3D sensor inaccuracies, this adaption process would have to be deployed by an additional human adaptive component (the teacher).

Development: Since popular exergames are 'locked in' and offer no access to source code, a series of purpose built *adaptable* video games were developed to allow for instant adaption of gaming parameters by a teacher. The next step was to track and record how the principled framework was delivered and to capture the adaption and deployment process required to ensure all principles could be supported through a video game environment in the classroom setting.

Deployment: With that, the initial deployment of video games, during the action research period, focused on a qualitative analysis of all the things *I* (the teacher) had to do. It involved a continuous tracking of the adaptive process, noting *when, how* and *why* game design features were adapted to suit individual needs of the learners; and included the monitoring of logistical, as well as set-up, considerations. Results were utilised to outline a *Teacher Adaption and Deployment Guide,* a rubric that other teachers could follow in order to deploy video games for locomotor acquisition in their own classrooms.

Evaluation: The effectiveness of this overall deployment process required evaluation from two perspectives. First, from the point of view of the teacher by tracking their experiences (were they capable of adapting games to meet learner needs and providing additional motor learning principles that the games could not?). Second, from the point of view of the children by tracking the effect gameplay had on locomotor acquisition (did gameplay lead to improved locomotor skills?). Teacher feedback and opinions were analysed to inform a new starting point and potential 'design blueprint' for future versions of video games for locomotor acquisition in the classroom. The sum of these parts stimulated the main research question, which now follows.

1.3 RESEARCH QUESTION

How can video games for locomotor acquisition be designed for effective deployment in the classroom?

The research question is answered by applying action research in the classroom setting through a rigorous cycle of design, development, deployment and evaluation. It is sub divided into parts and initially focused on how video games for locomotor acquisition are *designed* which includes (i) the articulation of an underpinning design framework, (ii) the development of adaptable video games, with adaptable design features and (iii) an outline of the adaptive process required between teacher and game to deliver this framework in full. Following this, the overall deployment process of video games for locomotor acquisition in the classroom is tracked and recorded. Results are utilised to outline a *Teacher Adaption and Deployment Guide*. Essentially, an easy to follow guide to assist teachers with adaption and overall deployment of video games for locomotor acquisition in the classroom.

The 'effectiveness' of deployment requires evaluation and is therefore explicitly stated in the research question. Effectiveness is measured in two parts, first from the point of view of the teacher i.e. are they capable of doing all of the things outlined for them in the Teacher Adaption and Deployment Guide; and second from the point of view of the user, i.e. does an extended period of game play lead to improved locomotor acquisition? Results ascertained over the action research period also speak to a potential blueprint for future, more sophisticated, versions of video games for locomotor acquisition. This means that the research objectives are threefold and concerned with (i) design (and development), (ii) deployment and (iii) evaluation.

1.4 RESEARCH OBJECTIVES

There are three research objectives (stemming from the research question) that this thesis aims to address:

1. Research objective one is to *articulate a principled design framework* that can be utilised to underpin video games for locomotor acquisition. This framework intends to be *agnostic,* capable of being delivered in a variety of ways across a variety of platforms. The construction of a principled design framework involves a systematic and 'inductive' analysis of the literature to identify empirically supported principles and conditions that facilitate improved motor acquisition. First, a list of all identified principles and conditions across the state of the art are compiled. These principles and conditions are then analysed and untangled further to identify patterns and ultimately, a 'recipe' or *framework* to support successful gross motor (including locomotor) acquisition. The framework is entitled *PaCMAn*: Principles and Conditions for Motor Acquisition.
2. Research objective number two is *to deliver PaCMAn through a video game experience in the classroom setting.* From a theoretical standpoint, this includes an analysis of: (i) affordable 3D sensor technologies, (ii) popular exergames and their design features and (iii) studies on the deployment of exergames for rehabilitation purposes, as well as purpose built video games for health, balance, strength, co-ordination and physical fitness. Findings will highlight parts of the framework that can be supported by the computer (game) versus parts of the framework that require the use of a *human adaptive component,* the teacher*.* Purpose built video games for locomotor acquisition with 'adaptable' design features will then be developed allowing PaCMAn to be delivered through an adaptive process between game and teacher. This delivery and the overall deployment of video games for locomotor acquisition in the classroom will be evaluated during a period of action research. Results will be used to inform a *Teacher Adaption and Deployment Guide*. The guide essentially outlines the delivery of PaCMAn through video gameplay in the classroom and the role of the teacher in terms of this delivery/deployment process. The adaptable games for locomotor acquisition outlined in this study were developed to provide a platform through which the main research question could be addressed; they were not intended to be sophisticated; however, they were intended to be effective.
3. Thus, the third research objective is to evaluate *the effectiveness of video games for locomotor acquisition in the classroom* (arising from objectives one and two). Effectiveness in this thesis is measured from two perspectives. First, from the point of view of the teacher i.e. are they capable of deployment; can they do all of the things outlined in the Teacher Adaption and Deployment Guide? Second, from the point of view

of the learner i.e. does an extended period of game play lead to improved locomotor acquisition? Several teachers will be provided with a guide and video games for locomotor acquisition for use in their own classrooms. Their experiences will be observed and their comments/feedback throughout will be recorded. Findings will speak to the reality of deploying video games for locomotor acquisition in the classroom and also provide useful information relating to how this deployment process could be improved for future reference. The effect of video games for locomotor acquisition on user performance will also be evaluated, quantitatively, over an eight-week period of video gameplay in the classroom. 48 children will be assessed at three points (pretest, interim test and posttest) over the research period. Perceived differences in motor acquisition from pretest to posttest will demonstrate the potential effect video games for locomotor acquisition have on user locomotor performance.

1.5 CONTRIBUTION

I previously developed an initial prototype of video games for locomotor acquisition as part of an M.SC in Technology for Learning. However, these games were effectively 'noise' and not the focus of the research. They were designed on intuition as opposed to theory and used as a vehicle to explore potential links between improved locomotor acquisition and improved reading fluency. The only people to benefit from the initial development of these games were the children who participated in the study. That is, the games were only outlined briefly in the study with little attention given to theoretical design or means of deployment. The dissertation's contribution was towards *teaching and learning* and specifically, the identification of a potential causality between locomotor acquisition and reading fluency.

In this thesis however, the main contribution is specifically towards *game design*. A major contribution is the construction and articulation of a principled framework potentially utilised to underpin the design and development of video games for locomotor acquisition. In this thesis several parts of this framework are delivered by a 'human adaptive component' through an adaptive process between teacher and game. The framework is intended to be agnostic and therefore capable of being delivered in a variety of ways. The framework is entitled *PaCMAn:* Principles and Conditions for Motor Acquisition and has arisen from an inductive meta-analysis of the literature on locomotor theory, training and acquisition.

Another lesser contribution is a Teacher Adaption and Deployment Guide. The guide outlines what teachers have to do in order to deploy video games for locomotor acquisition in the classroom. It refers to the overall delivery of PaCMAn in a video game environment and gives specific detail on the adaptive process required between teacher and game to facilitate an 'effective' locomotor training experience.

This leads to the final contribution, results of an evaluation that speak to the effectiveness of video games for locomotor acquisition outlined in this thesis. These results provide empirical evidence to support the use of video games for locomotor acquisition in the classroom. They also reveal the capabilities of teachers in terms of the deployment process and provide insights into improvements that could be made for future versions of video games for locomotor to potentially bridge the gap between the research and practice.

1.6 THESIS OVERVIEW

1.6.1 CHAPTER 2: STATE OF THE ART

The state of the art begins with an overview of the literature on gross motor acquisition and more specifically, locomotor acquisition. An outline of recent studies linking locomotor acquisition to health and academic performance is used to emphasise the importance of effective locomotor skills in childhood. Conversely, empirical evidence is presented to highlight significantly decreased levels of locomotor skills demonstrated by modern day children relative to children in the past. This decrease in skill acquisition is attributed to an increased sedentary lifestyle and new forms of play habits including online interactions and video gameplay.

The prospect of converting video gameplay (typically described as a barrier to locomotor acquisition) into a potential training platform is then addressed. This begins with the analysis of studies that refer to the use of exergames (commercial as well as purpose built) to train and improve health, physical fitness, basic motor movements, balance, co-ordination and even object control skills. A further analysis into the limitations of 3D sensor technology (Kinect 1 & 2) reveals prominent inaccuracies and thus, potential difficulties utilising video games for locomotor acquisition purposes.

These technical difficulties are compounded by theoretical difficulties. That is, the failures of non-virtual training programs to support significant gains are revealed to be a lack of theoretical principles (or rules) underpinning design. Thus, highlighting a gap; that is, a theoretical framework (for locomotor or gross motor acquisition) does not yet exist in the literature. Accordingly, the state of the art concludes with a systematic analysis of gross motor theory and empirically supported studies on gross motor training and acquisition. This leads to the identification of an 'inductive' list of motor learning principles (rules) and conditions (factors) dispersed across the literature, providing a set of ingredients with which to establish a 'principled framework', later constructed and articulated in chapter 3.

1.6.2 CHAPTER 3: DESIGN OF FRAMEWORK

Having exposed a gap in the literature for a principled framework to support motor training and acquisition, chapter 3 begins by dissecting the list of principles and conditions (identified at the end of chapter two), analysing this list for patterns and eventually, articulating a generalised framework. This involves bringing a uniformity of language to principles that hold the same or similar meaning iterated in different ways across the literature. It also involves sequentially reducing the amount of choice by limiting the number of principles (rules) on offer. This is achieved by focusing in on principles that demonstrate significant effects on learner acquisition and by clustering similar principles/rules together under one over-arching heading. Ultimately, a framework should be functional and as such, the final part of the framework's design is concerned with supporting the decision making process i.e. which combination of principles and conditions best support individual learner needs. Consequently, a learner assessment is devised, the results of which are used to inform the practitioner around which set of rules and factors (principles and conditions) best support individual learner needs. The chapter concludes with an illustration and example of the newly constructed framework and its deployment in a classroom setting.

1.6.3 CHAPTER 4: DEVELOPMENT OF GAMES

In chapter 4, the theoretical framework articulated in chapter 3 is used to underpin the design and development of video games for locomotor acquisition. The hypothesis is that video games built on this framework will support effective locomotor acquisition through deliberate gameplay. The chapter is largely concerned with the delivery of PaCMAn in a video game environment. Popular exergames already on the market are analysed against the PaCMAn framework. A number of 'design features' found to correlate directly with motor learning principles and conditions are identified. Other principles and conditions are identified as being 'virtually' impossible to support because of technical limitations. These 'parts' of the framework are however, potentially delivered through the use of a human adaptive component and expert, the teacher. The chapter concludes with a hypothetical and macro outline of what the teacher is expected to do, i.e. how the adaptive/delivery process is deployed.

1.6.4 CHAPTER 5: EVALUATION

Chapter 5 outlines the data collection process as well as the results and findings from a period of action research involving the deployment of video games for locomotor acquisition in the classroom. An initial period of action research results in an outline of a Teacher Adaption and Deployment Guide. Game design and deployment is then evaluated from two perspectives. First from the point of view of the teacher i.e. could they adapt parameters of gameplay for the learner and deliver other absent principles? Second from the point of view of the learner, did an extended period of gameplay lead to improved locomotor acquisition? Quantitative findings provide empirical evidence to support the use of video games for locomotor acquisition in the classroom. Qualitative findings suggest that teachers are not only capable of deployment but actually empowered by their role and responsibilities whilst also providing a significant amount of information to inform a potential blueprint for future, more sophisticated, versions of video games for locomotor acquisition.

1.6.5 CHAPTER 6: CONCLUSION

Chapter 6 discusses the conclusions of this thesis examining the extent to which this thesis met the research objectives. It includes a specific outline of the contributions made and addresses the issue of future work that could be conducted to potentially extend/enhance the research further. The chapter (and thesis) concludes with a discussion and design blueprint on future, more sophisticated versions of video games for locomotor acquisition.

2 STATE OF THE ART

2.1 GROSS MOTOR ACQUISITION

Gross motor acquisition refers to a growth in athletic *skills* that use large muscles in the legs and arms. These skills emerge dynamically in predictable stages. First, a 'rudimentary stage' (0-3 years) involves the development of balance, crawling, bending, twisting and dodging (Ignico, 1994; Gallahue et al., 2012) generally referred to as *stabilising movements*. This stage is followed by the development of 'fundamental movement skills' which are divided into two subsets, (i) **locomotor skills**: *run, hop, skip, jump, slide* and (ii) **object control skills**: *kick, bounce, throw, catch* and *bat*. Part of this dynamic development sequence is illustrated below (figure 2.1).

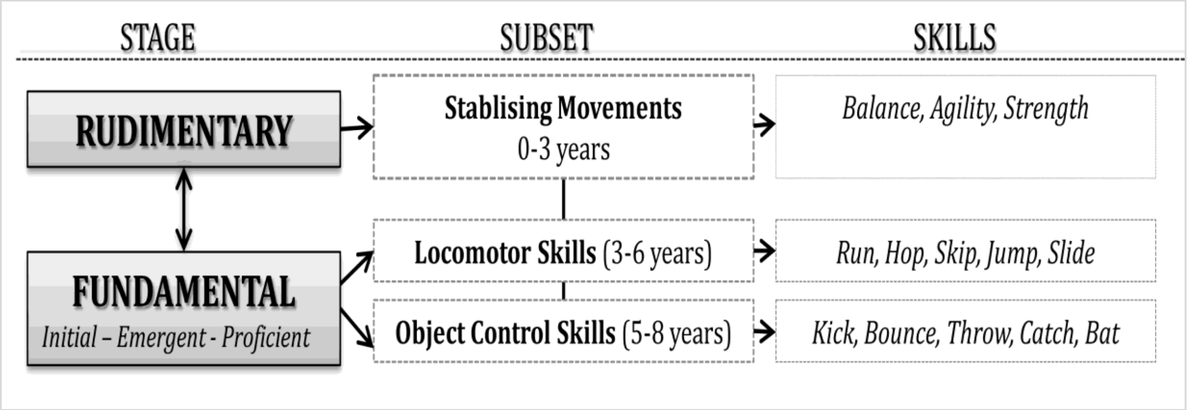
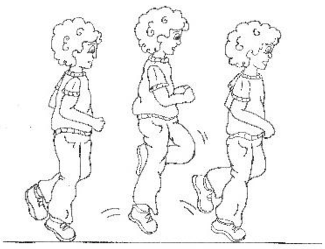


FIGURE 2.1 GROSS MOTOR DEVELOPMENT: STAGE.SUBSET.SKILLS

Locomotor acquisition typically takes place sequentially between the ages of 3-6 years old. An *initial stage* of locomotor acquisition is marked by poorly performed inaccurate movements. It is followed by an *emergent elementary stage* (4-5 years) in which the child demonstrates greater motor control and improved rhythm (Ignico, 1994; Gallahue et al., 2006 & 2012). A *proficient stage* is typically reached by the age of 6 and refers to locomotor skills that are performed with highly co-ordinated and 'effective' *performance criteria* (Ulrich, 2000). These performance criteria refer to the *parts* of a locomotor skill that the learner is required to perform. Typically, a hop, skip or jump performed with full performance criteria denotes effective locomotor acquisition. Criteria for each locomotor skill is laid out by Ulrich (2000) in the diagnostic assessment, Testing Gross Motor Development-2. The criteria for several locomotor skills has been illustrated below (table 2.1) for the purpose of this thesis.

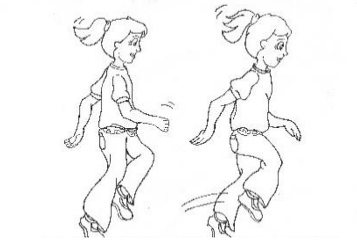
TABLE 2.1 LOCOMOTOR PERFORMANCE CRITERIA (ILLUSTRATIONS ORIGINAL TO THIS THESIS, TEXT BASED ON CRITERIA OUTLINED IN TGMD-2, ULRICH, 2000)

Hop



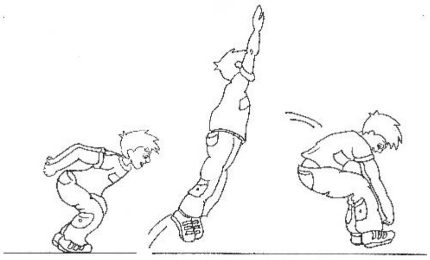
1. One foot lifted, bent at the knee, carried behind body
2. Lifted foot rotates in circular fashion to generate force
3. Arms bent at the elbow and swing forward on take off
4. Hop on right and left foot

Skip



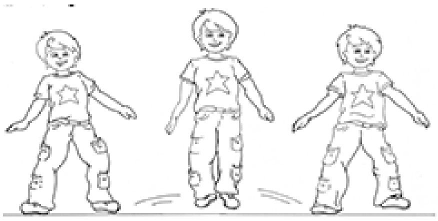
1. Rhythmic pattern of step, hop on alternating feet
2. Foot of non-support leg carried low to the ground
3. Arms move bilaterally in opposition to the legs

Jump



1. Bend both knees and extend arms behind body
2. Bring arms forward and upwards to full extension
3. Land with both feet together
4. Arms are brought downwards on landing

Slide



1. Turn body sideways
2. Step sideways and slide following foot to meet
3. Both feet momentarily together off the ground
4. Be able to slide both left and right

Standardised norms from the TGMD-2 (Ulrich, 2000) indicate that full performance criteria are rarely performed or explicitly taught. A large scale study by Sander and Kidman (1998) revealed that up to 50% of children attending primary school (or elementary school) in New Zealand, did not demonstrate proficient or effective gross motor skills. Further, a recent study from Ireland found that 89%, of the 242 adolescents assessed, failed to demonstrate proficient fundamental motor skills (O'Brien et al., 2014). Effectively, only 11% of Irish teenagers possess skills typically mastered by 6 year olds. Interestingly, skill proficiency in the locomotor subtest was also lower than the object control subtest. Evidence suggests that from country to country, the majority of children fail to demonstrate proficient locomotor skills (O'Brien et al., 2014). Furthermore, children who do not demonstrate full performance criteria are deemed to be in the 'at risk' category (Ulrich, 2000) and are more likely to maintain poorly developed locomotor skills throughout their lives.

The consequences of poor locomotor performance are manifold. Research points to a cause and effect relationship between poor locomotor skills and poor performance elsewhere including speech and language (Olander, 2010), behaviour (Brossard-Racine et al., 2011) and health (Pica, 2008). Poor gross motor skills are also a significant predictor of non-participation in sports in later life. This significantly increases the risk of (i) obesity (ii) low self-esteem and (iii) low social confidence. Seefeldt (1980) states that children require a certain level of locomotor acquisition in order to break through a metaphorical 'proficiency barrier' and engage in sport in later life. Children who do not break through this proficiency barrier are more likely to experience mental health issues in adolescence or adult years (Stodden et al., 2008). Recent literature also points towards a correlation between fundamental motor skills and cognitive development (see: Van Der Fels et al., 2014; McPhillips & Sheehy, 2004). That is, children who present with poor locomotor skills and/or poor object control skills often present with co-morbid difficulties in reading and mathematics (Westendorp et al., 2014). This link between motor and cognitive developmental is threefold, (i) they share similar developmental timetables, (ii) they make use of the same brain structures and (iii) both domains call upon a set of common brain processes including executive functions, visual processing and pattern identification (Diamond, 2000; Westendorp et al., 2014). Hypothetically, one could develop a series of brain processes through locomotor training and acquisition and later distribute them to a related cognitive task.

Conversely, the modern child demonstrates poor locomotor skills (O'Brien et al., 2014; Goodway & Branta, 2003) owing to an increased sedentary lifestyle and new forms of play from which acquisition cannot occur. The fact is, children in the past acquired gross motor skills, particularly locomotor skills, through self-generated practice of popular pastimes including hop-scotch, skipping and leap frog (Akbari et al., 2010; McPhillips & Sheehy, 2004).

Nowadays children spend at least three hours a day and up to 25 hours a week watching TV or playing video games (Guthol et al., 2010) both of which are often cited as having a negative impact on physical fitness and locomotor acquisition in children (Straker et al., 2011). However, with the emergence of 3D sensor interfaces, video games can now support full body gross motor interactions. A new genre of exergames have emerged, some of which call upon the user to run, hop and jump in order to control a game character and achieve success. Thus, video games potentially offer a platform to support locomotor acquisition, transforming part of the problem into part of the solution. Whilst there is a significant lack of research relating to the use of video games as a tool to support *locomotor* acquisition; a number of studies have examined the use of video games to improve health and specifically physical fitness, balance, co-ordination, sports related skills and the acquisition of *basic* gross motor movement. Several studies also examine the effect of gameplay on object control skills in both children and adults. The results of these studies speak to the potential platform video games have to offer locomotor acquisition in the classroom setting.

2.2 VIDEO GAMES AND PHYSICAL ACTIVITY

For previous generations, self-generated play and popular pastimes involved significant physical activity, energy expenditure and the practice of sports related skills. Nowadays, popular pastimes are more sedentary. For example, video gameplay is typically considered an inactive finger tapping experience. Many argue that traditional video games are largely responsible for physical inactivity observed in modern children (Vanderwater et al., 2004; Sothern, 2004). However, in recent years the way we control video games has shifted to provide more immersive user experiences. Essentially, 3D sensor technologies are now linked with game consoles to elicit full body gross motor interactivity (Cassola et al., 2014). Affordable devices such as the *Microsoft Kinect* make use of video camera and infra-red depth sensor to form a coloured cloud of around 300,000 dots per frame. An algorithm identifies specific anatomical landmarks (20 with Kinect 1, 25 with Kinect 2) from these dots in 3D space (Xu & McGorry, 2015). This means that users can now control a video game with their whole bodies, not just their hands. Additionally, fingertip sensors (Nintendo) and arm sensors (Xbox 360) also capture information relating to the user's vital parameters e.g. heart rate and pulse; whilst the Wii Balance Board captures information relating to a user's centre of balance. Accordingly, a new genre of *exergames* calls for physical activity and even gross motor outputs as a means of game control. Users are asked to demonstrate fitness and perform sports related skills to achieve success. Most exergames are designed for recreational purposes (Levac, 2014; Vernadakis et al., 2012) however, there are several games, or gaming series, explicitly marketed towards health and fitness. Thus, the genre offers an interesting study into the potential platform video games have to offer the training and acquisition of both object control and locomotor skills.

Indeed, exergames are widely studied from a research perspective. A large amount of this literature is focused on their capacity to elicit *physical activity* and thus, to identify the level of *energy expenditure* experienced by users during gameplay. Biddiss & Irwin (2010) reviewed 18 studies on physical activity and exergames. Their findings indicate that users experience an overall 'light to moderate' level of energy expenditure. Best (2012) and Barnett et al. (2011) came to similar conclusions. Essentially, whilst widely available exergames have found their way into the school setting as part of physical education and after school programs (Levac, 2014; Kiili & Perttula, 2012) they cannot match the same upper levels of energy expenditure experienced through real-world training (Kliem & Weimeyer, 2006). This is a result of the fact that commercial/popular exergames are largely ‘one size fits all’ and do not adapt parameters of gameplay to meet individual user needs (Hardy et al., 2011). Conversely, *personalised* exergaming experiences could potentially elicit higher levels of energy expenditure and compare more favourably to real-world training scenarios.

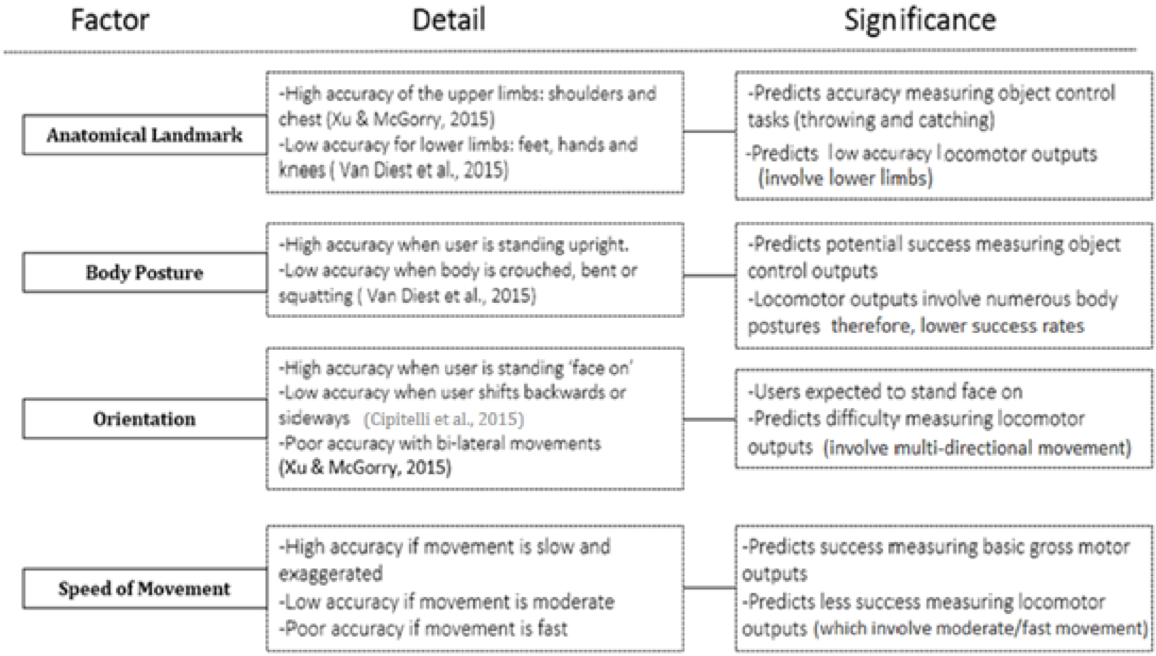
In order to increase levels of energy expenditure, an accurate assessment of the learner’s vital data should be carried out (Kreymann et al., 2009) and the results utilised to inform parameters of practice. Within a gaming environment, expensive marker or wearable sensor based systems are capable of this kind of assessment; however, for economic reasons, they are less likely to be found in homes or schools. In contrast, affordable ‘off the shelf’ sensors are far more popular and provide an opportunity to facilitate an immediate relocation of fitness training (and potentially gross motor training) to a video gaming environment (and in turn, the home and classroom setting). That said, affordable sensors are typically less reliable. Indeed, several have been recalled from the market (e.g. Nintendo’s ‘vitality’ finger sensor, 2009) owing to ‘testing issues’ i.e. inaccurate and incorrect assessment results (McFerran, 2013). This alludes to the fact that whilst sensor technologies are promising in terms of transforming recreational gameplay into a veritable training platform, the accuracy with which affordable sensors capture data may not always be enough to surpass real world training.

Furthermore, to examine the potential use of exergames for locomotor training and acquisition, it is important to examine the capabilities of affordable 3D sensor technologies (e.g. Kinect, PrimeSense etc.) required to capture *gross motor* outputs and data, i.e. skill criteria, force, speed, distance etc. Accuracy of this data is crucial in order to match parameters of gameplay with individual/physiological needs of the user and personalise gaming experiences. Whilst affordable 3D sensor technologies are likely to improve, and probably soon; at present, they demonstrate several limitations that render accurate assessment of user locomotor skills ‘technically’ difficult.

2.3 LIMITATIONS OF AFFORDABLE 3D SENSORS

Affordable 3D sensors lack an equality of accuracy for all anatomical landmarks, body postures, movement orientation and movement speed (Clarke et al., 2012, 2013). Sensors are particularly inaccurate measuring joints and movements in the lower part of the body. A summary of these inaccuracies is illustrated and outlined below (table 2.2) for the purpose of this research.

TABLE 2.2 SENSOR ACCURACY: FACTOR.DETAIL.SIGNIFICANCE



Factor	Detail	Significance
Anatomical Landmark	-High accuracy of the upper limbs: shoulders and chest (Xu & McGorry, 2015) -Low accuracy for lower limbs: feet, hands and knees (Van Diest et al., 2015)	-Predicts accuracy measuring object control tasks (throwing and catching) -Predicts low accuracy locomotor outputs (Involve lower limbs)
Body Posture	-High accuracy when user is standing upright. -Low accuracy when body is crouched, bent or squatting (Van Diest et al., 2015)	-Predicts potential success measuring object control outputs -Locomotor outputs involve numerous body postures therefore, lower success rates
Orientation	-High accuracy when user is standing 'face on' -Low accuracy when user shifts backwards or sideways (Cipitelli et al., 2015) -Poor accuracy with bi-lateral movements (Xu & McGorry, 2015)	-Users expected to stand face on -Predicts difficulty measuring locomotor outputs (involve multi-directional movement)
Speed of Movement	-High accuracy if movement is slow and exaggerated -Low accuracy if movement is moderate -Poor accuracy if movement is fast	-Predicts success measuring basic gross motor outputs -Predicts less success measuring locomotor outputs (which involve moderate/fast movement)

Table 2.2 highlights the fact that affordable 3D sensors (Kinect) are more effective where movements are (i) upright (ii) face on (iii) slow, exaggerated and (iv) involve the upper limbs.

Limitations of the Kinect sensor (Xbox 360) were seemingly acknowledged by Microsoft and a second version was brought to market in 2014. Kinect version two (V2) is more precise and has more features. It captures additional joints at the hand tip, thumb tip and neck. It also captures the hand opening/closing. However, the accuracy with which these additional joints are captured are dependent on the same factors as Kinect V1 (table 2.2). For example, the foot and ankle joints of Kinect V2 are offset from the ground plane (Wang et al., 2015). This means the feet, particularly their orientation, cannot be assessed with a great deal of accuracy. In general, the lower legs and lower limbs can only be accurately captured if the user is upright and moving slowly and/or deliberately. Indeed, Kinect V2 was evaluated as an effective tool for clinical measurement of *basic* gross motor movements e.g. standing up, sitting down, walking on the spot and in a straight line (Otte et al., 2016) but has yet to be outlined as a tool that supports accurate assessment of locomotor skill criteria; and to that end, affordable 3D sensors in their current state cannot compare with more expensive marker or wearable sensor based systems. However, given the current rate of improvement, this may well change in the near future.

2.4 VIDEO GAMES AND OBJECT CONTROL SKILLS

At present, 3D sensors (incl. Kinect V1 & V2) are more accurate when measuring specific *types* of motor outputs and skills. Consequently, there are relatively few commercial exergames that explicitly call for locomotor outputs from the user. This implies game designers are mindful of sensor limitations and avoid developing games in which outputs are not accurately measured. On the other hand, many popular exergames call for *object control skills* from the user (throw, catch, kick, bounce etc.). An analysis of table 2.2 (previous page) highlights the fact that these skills are relatively well tracked by affordable sensor technology. Consider batting a ball in a virtual game of baseball. The user's feet are fixed to the floor, he/she is stood in an upright position, shoulders and arms are predominantly moving in one direction, towards the sensor. The output is face on and exaggerated thus, accurately and effectively measured.

Whilst popular exergames are not purposely designed to target object control skill acquisition, there are already some examples of their use for this purpose. For instance, Nintendo Wii Sports was deployed in a study to investigate if a team of basketball players could improve their 'throw' in a virtual training environment. The study found that improved throwing could be identified during 'virtual' practice sessions but that these improvements were not transferred to real life play (Wiemeyer & Schnieder, 2012). More recently, Vernadakis et al., (2015) examined the effects exergaming (in the classroom) had on object control acquisition in a group of children. A series of popular exergames were chosen to elicit the practice of several object control outputs and a strict schedule of gameplay was adhered to. Results indicate that object skills *could* be improved through virtual training *and* that skills transferred to real world performance. Interestingly, positive findings from this study are potentially attributed to the fact that these games were deployed by "an experienced motor skill instructor" (p. 96) who provided additional demonstrations on correct object control criteria. Thus, it appears that the presence of the (human) instructor during gameplay represents a significant factor in the success of the games in this study, relative to (similar) games deployed by Wiemeyer & Schnieder (2012). Also of note is the fact that Vernadakis et al. (2015) state that, in general, teachers lack knowledge and understanding of how to deploy exergames for the purpose of training object control skills. Ergo, the deployment process potentially requires analysis leading to some form of *guidance rubric*; particularly for teachers who don't class themselves experts in the target instruction (e.g. motor acquisition and training) and/or video gameplay.

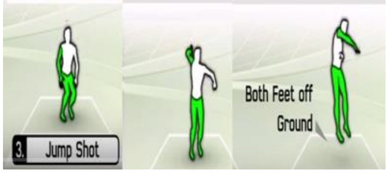
2.5 VIDEO GAMES AND LOCOMOTOR SKILLS

Thus far, the use of exergames as a training platform for physical fitness and object control skills have been addressed. Beyond this, the genre has also gained in popularity as a tool for the maintenance of basic motor movements in elderly care e.g. lifting arms above head (Mastorakis & Makris, 2012; Clark et al., 2012; Wiemeyer & Kliem, 2012; Maggiorini et al., 2012) and the rehabilitation of basic motor movements in stroke patients and people with Parkinson's, e.g.

retraining use of the arms, bringing hand to mouth etc. (Crosbie et al., 2007; Saposnik & Levin, 2011; Pastor et al., 2012; Shiratuddin et al., 2012; Levac, 2015; Galna et al., 2014). Several studies have also explored the use of exergames to facilitate improved balance (Hammond et al., 2014; Sheehan and Katz; 2013; Vernadakis et al, 2012; Salem et al., 2012; Kliem & Wiemeyer, 2010). An analysis of sensor accuracy demonstrates a high level of effectiveness when movements are slow and involve the upper body with single orientation. Consequently, the use of exergames to support basic motor movements and even object control skills is perhaps expected. Additionally, the Balance Board (Nintendo Wii) has returned reliable and consistent measurements (Clark et al., 2010); ergo, successful use of popular and/or purpose built exergames (with Balance Board) to facilitate improved balance in users, is also to be relatively expected.

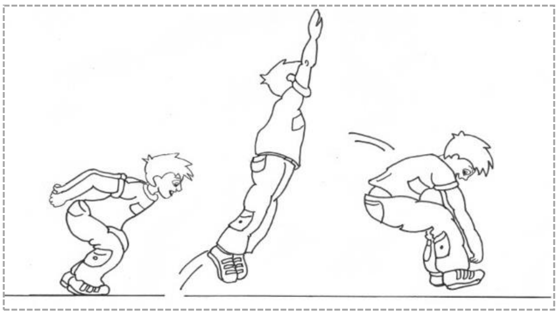
On the other hand, no study could be identified in the literature relating to the use of video games for the training and acquisition of locomotor skills. This is perhaps unsurprising given that characteristics of locomotor performance, small movements, use of the lower limbs and multiple orientations are predictors of poor sensor accuracy. Despite these apparent limitations, an analysis of popular exergames on the market lead to the identification of several games that call upon the user to perform locomotor outputs as a means of game control. Table 2.3 presents a description of four such exergames. Particularly of note, is the fact that each game presents a virtual demonstration of the locomotor 'control output' which, for the most part, happens to compare favourably to locomotor criteria outlined in TGMD-2 (Ulrich, 2000). A description of these games follows.

TABLE 2.3 DESCRIPTION OF EXERGAMES WITH LOCOMOTOR OUTPUTS

Game	Objective	Locomotor Output(s)	Demonstration
Jump Rope (Your Shape: Fitness Evolved) Xbox 360	A jump rope workout designed to support physical activity and relatively high energy expenditure	Game involves consecutive jumps and also calls for the user to **hop.** This hop is modelled by digital character with near full criteria	 HOP
Volleyball (Kinect Sports) Xbox 360	A recreational game of volleyball in which user has to jump and strike ball over a net	Presents a pre-practice model of a **jump** with near full criteria	 JUMP
Kicks (EA Sports Active) Wii	Fitness program (for adults) – absence of 'game' objective	Requires repetitive and rhythmical kicks. This pattern is essentially a **skip** slowed down and broken into parts	 SKIP
Goal Keeper (EA Sports Active) Wii	Fitness program – with game objective	Goal keeper models a **slide** in both directions. User is prompted to imitate this output	 SLIDE

Virtual demonstrations in these games accurately model intended locomotor outputs. However, in reality, users typically cheat outputs to limit energy expenditure (Gao & Mandryk, 2012) and 3D sensors fail to identify these inaccurate movements. In addition, users can cheat by altering their own distance from the sensors. That is, a user can reduce an intended jump to a basic arm lift by moving closer to a sensor.

To review, a proficient (proper) jump consists of 4 criteria outlined below (fig.2.2).



1.KNEES BENT, ARMS BEHIND BODY
2.ARMS EXTENDED FORWARD AND UP ABOVE THE HEAD
3.TAKE OFF AND LAND ON BOTH FEET SIMULTANEOUSLY
4.ARMS BROUGHT FORCEFULLY DOWN TOWARDS FEET

FIGURE 2.2 THE CRITERIA OF A PROFICIENT JUMP (INFORMED BY ULRICH, 2000)

Several videos described as 'gameplay demonstration' were discovered online (Kinect Sports Track and Field, 2012; Kinect Sports Game Guide, 2010) and allow for a comparison between the model presented by a game versus the output typically performed by the user. As expected, outputs performed by 'gamers' in these videos and the output modelled by the game were not in line with one another. This point has been illustrated for the purpose of this research in figure 2.3 (below).

Pre Practice Model Typical User Output

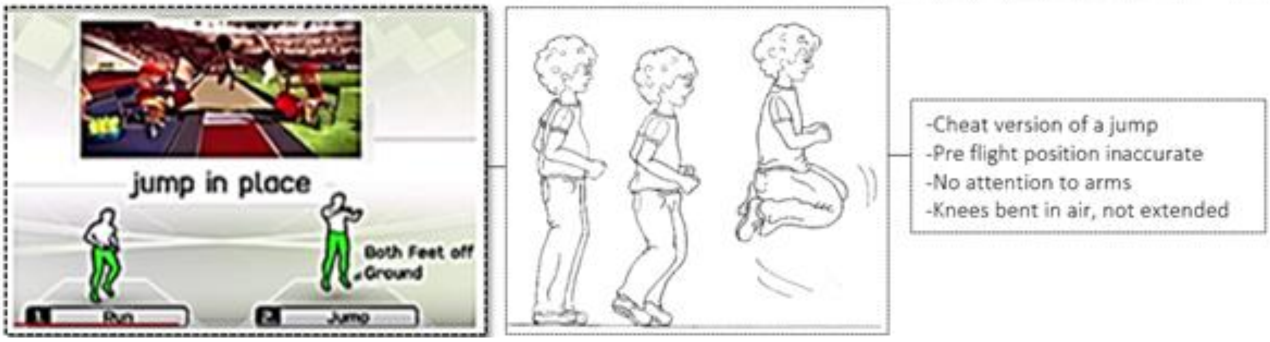


FIGURE 2.3 MODEL VERSUS TYPICAL USER OUTPUT

Given the previous, the design of purpose built video games for locomotor acquisition is potentially blocked by 3D sensor inaccuracy which prevents an accurate assessment of user criteria and facilitates cheated outputs. However, several studies suggest that technical limitations can be negotiated; through the use of an additional 'human' component.

2.6 HUMAN ADAPTIVE COMPONENT

A number of empirically supported studies refer to the use of video games for the acquisition of physical fitness, basic gross motor skills and object control skills (Göbel et al., 2010; Shiratuddin et al., 2012; Galna et al., 2014; Levac, 2015; Vernadakis et al., 2015). Following an analysis of these studies it becomes apparent that the human (teacher, clinician or instructor) plays a potentially significant role in effectively deploying video games for both fitness and motor learning purposes. Indeed, several studies involving the use of popular exergames for motor rehabilitation describe a decision making process in which the clinician (i) chooses a game to elicit an appropriate motor output (Levac et al., 2015), (ii) alters the user's distance from the sensor to stimulate a more basic or complex physical response (Galna et al., 2014) and (iii) terminates game play when the patient presents as fatigued (Levac et al., 2015). This could be described as 'adaption' i.e. the process of adjusting a system/game in order to meet a certain goal. Vernadakis et al. (2015) make reference to the fact that the teacher (an experienced motor control instructor) provides verbal prompts and physical demonstrations at runtime, thus, accounting for what could be described as the provision of additional *direct instruction* (verbal and/or physical) not provided by the game. In both scenarios, the clinician/teacher could be described as a 'human adaptive component', a potentially crucial part of transforming video games into an effective gross motor training and acquisition platform. A human adaptive component essentially, (i) adapts parameters of gameplay to meet individual user capabilities and (ii) provides additional (expert) information in line with user needs. This process combines the capabilities of a gaming system with a veritable 'human intelligent system' allowing the teacher (or clinician or instructor) to become a powerful part of deployment.

In order to facilitate a marriage between game and human, it is important to facilitate human adaption. To that end, commercial exergames on the market are rarely adaptable (Webster & Celik, 2014). Further, teachers, (or clinicians or instructors etc.) typically lack experience in coding and work on tight schedules, which means an adaptive process should entail little more than a click, slide or drag of a button. Interestingly, Göbel et al. (2010) outline a set of instantly adaptable exergames for health (ErgoActive) that were developed in StoryTec (Göbel et al., 2008). The choice of authoring tool affords access to a 'property editor' allowing for 'on the fly' adaption of several gaming parameters with relative ease. Adaptable video games are therefore a viable option and a marriage between game and human could become a reality.

However, a final challenge remains. That is, the role of the human requires guidance and support so that adaption, and the overall deployment process, is not merely based on intuition but rather, *theoretically* informed. Indeed, the main issue facing (non-virtual) locomotor training and acquisition programs is that they lack an understanding of motor learning theory (Gallahue et al., 2012; Houwen et al., 2014). Thus, in order for video games to provide an effective locomotor training platform, the design, development and deployment (which includes adaption) should take a theoretical and *principled* approach. This presents as a particular problem as researchers in motor training and acquisition admit to being unsure as to what motor learning principles (rules) or even; what combination of principles, best support effective gains (Lee & Schmidt, 2008; Maas et al., 2008). Consequently, video games for locomotor acquisition can only become a reality if game designers tackle both technical *and* theoretical shortcomings.

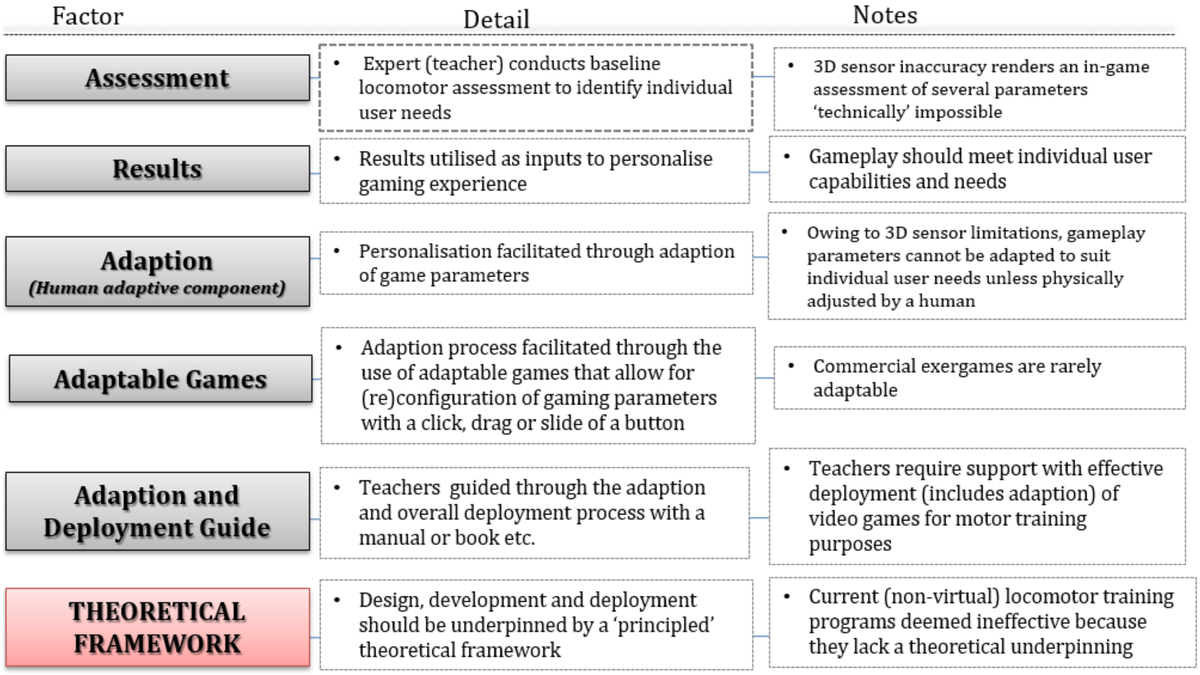
2.7 PURPOSE BUILT VIDEO GAMES FOR LOCOMOTOR ACQUISITION IN THE CLASSROOM

Thus far, we know that new sensor technologies afford gameplay an opportunity to shift from a sedentary finger tapping activity into an immersive experience eliciting full body/gross motor outputs. We also know that few commercial video games are purposely designed to target gross motor acquisition in users. This is potentially a result of the fact that 3D sensors have several limitations including poor accuracy measuring specific parts of the body. Whilst some popular exergames are marketed towards the improvement of user fitness, studies indicate that these games rarely personalise parameters of play to meet user physiological makeup. This lack of personalisation stems from the fact that commercial video games are incapable of accurately assessing many facets of user performance and consequently, cannot use these as inputs to inform parameters of gameplay. Ergo, commercial video games are currently no substitute for real life training.

That said, commercial exergames have been effectively deployed by clinicians to support the rehabilitation of *basic* gross motor skills. Successful use of video games in this context appears to be heavily dependent on the presence of the 'expert' who adapts several parameters of play to suit patient needs. Human adaption could be supported further with 'adaptable video games' that offer the clinician/teacher a chance to instantly reconfigure gaming parameters with minimal effort. Equally, the adaption and overall deployment process requires guidance and support.

Given the previous, video games for locomotor acquisition in the classroom could become a reality by taking the following factors into account:

TABLE 2.4 VIDEO GAMES FOR LOCOMOTOR ACQUISITION: POTENTIAL DESIGN FACTORS



Factor	Detail	Notes
Assessment	• Expert (teacher) conducts baseline locomotor assessment to identify individual user needs	• 3D sensor inaccuracy renders an in-game assessment of several parameters 'technically' impossible
Results	• Results utilised as inputs to personalise gaming experience	• Gameplay should meet individual user capabilities and needs
Adaption ***(Human adaptive component)***	• Personalisation facilitated through adaption of game parameters	• Owing to 3D sensor limitations, gameplay parameters cannot be adapted to suit individual user needs unless physically adjusted by a human
Adaptable Games	• Adaption process facilitated through the use of adaptable games that allow for (re)configuration of gaming parameters with a click, drag or slide of a button	• Commercial exergames are rarely adaptable
Adaption and Deployment Guide	• Teachers guided through the adaption and overall deployment process with a manual or book etc.	• Teachers require support with effective deployment (includes adaption) of video games for motor training purposes
THEORETICAL FRAMEWORK	• Design, development and deployment should be underpinned by a 'principled' theoretical framework	• Current (non-virtual) locomotor training programs deemed ineffective because they lack a theoretical underpinning

Table 2.4 concludes by highlighting one factor above others, i.e. a theoretical framework. This framework is particularly necessary as current (non-virtual) training programs are deemed ineffective owing to a lack of underpinning *motor learning theory* (Gallahue et al., 2012; Houwen et al., 2014). As such, all aspects, i.e. design, development and deployment (including adaption), of video games for locomotor acquisition, should be theoretically informed. Herein lies a significant issue. That is, we do not know what motor learning *principles* (rules), or combination of motor learning principles, best support locomotor gains. Further, motor learning principles are often examined in isolation or at best, in small clusters across the literature (Wulf & Shea, 2002). This makes the 'ingredients' for effective gains difficult to track; thus, an overall 'recipe' or *principled framework* for success is equally challenging to decipher.

Hypothetically, a principled framework could be utilised to inform (i) design, by correlating game features and parameters of play with motor learning principles; (ii) development, by highlighting specific features that need to be 'adaptable' and (iii) deployment, by indicating which principles can be supported 'virtually' and which principles require a human adaptive component. Accordingly, a principled framework could act as a significant stimulus for the realisation of video games for locomotor acquisition in the classroom.

Consequently, the following section will provide a systematic analysis of the literature on gross motor learning and acquisition with the intention of identifying empirically supported *principles* (rules) and *conditions* (parameters) that facilitate effective motor acquisition. This will involve a rigorous analysis of studies on locomotor acquisition culminating in an inductive list.

In chapter three, this list will provide the ingredients with which to identify patterns and form a generalised framework. As such, the following section will discuss significant motor learning theories (Dynamic Systems Theory and contemporary theories). This will highlight principal areas that can be utilised to frame and organise principles and conditions for motor acquisition found in the literature.

2.8 THE INGREDIENTS OF EFFECTIVE MOTOR ACQUISITION

Motor learning involves the acquisition of *procedural knowledge* i.e. how to ride a bike, how to jump a rope, etc. This differs from *declarative knowledge* which involves knowing that something is the case e.g. 'a' is the first letter of the alphabet. Acquisition of procedural knowledge is not widely researched and consequently, not fully understood (Lee & Schmidt, 2008). What we do know is that procedural knowledge (which includes gross motor acquisition) does not simply come with maturation but rather, dependent on a number of factors (Gabbard, 2008; Payne & Isaacs, 2002). *Dynamic systems theory* and ecological approaches teach us that motor acquisition relies on interactions between (i) the learner (ii) the task and (iii) the environment (Newell, 1986). Specifics of this dynamic relationship are outlined in figure 2.3.

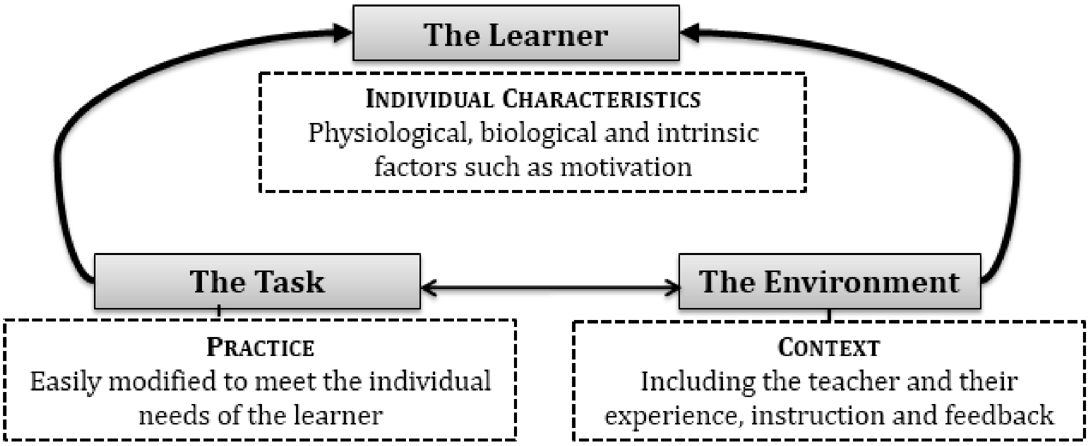


FIGURE 2.4 LEARNER.TASK.ENVIRONMENT

The **learner** presents with individual characteristics, previous experience, level of skill, motivation and willingness to learn. Given that every learner is different, a significant challenge is to meet their individual needs (Goodway & Robinson, 2006). Therefore, **the task** is an activity presented to a learner that can be modified to facilitate appropriate challenge that matches individual learner needs. Absolute timings and strength (the force or energy of the physical movement skill) are instigated by the parameters (or conditions) of the task. For example, kicking involves a forward and backward swing of the foot and leg (Maas et al., 2008). However, the force, direction, length and height are dependent on the placement of a goal relative to the position of the learner. Conversely, the parameters of a task are also dictated by the **environment,** e.g. the physical setting and equipment available. In addition, the environment includes the instruction and feedback afforded to the learner by their peers, teacher/instructor.

Similarly, contemporary theory states that motor development is reliant on **practice** [which correlates with *the task*], **instruction** [which correlates with *environment*] and **feedback** [also correlates with *environment*] (Schmidt & Lee, 2005; Gallahue & Ozmun, 2006; Gabbard, 2008). This essentially redefines the task as 'practice' and the environment as both 'instruction' and 'feedback'. Ultimately, Dynamic Systems Theory and contemporary theory point towards four overarching principal areas that frame motor acquisition: (i) Learner (ii) Practice (iii) Feedback and (iv) Instruction.

2.8.1 A PRINCIPLED DESIGN FRAMEWORK: FIRST STEP

At a macro level, motor acquisition relies on a dynamic interaction between learner, practice, instruction and feedback. On a micro level, there are a wide range of principles (rules) and conditions (parameters) within each area that need to be met. The choice of principles and their related conditions can have lasting effects on acquisition. Research has come a long way in terms of identifying and outlining the *principles/conditions* that lead to success. For example, we now know that a *practice schedule* should be adhered to (Wulf & Shea, 2002). This can include *blocked* practice of the same or similar skills (for inexperienced learners) or random practice of multiple skills (for more experienced learners). In addition, the *timing of feedback* is important and can be delivered *concurrently* (during practice) or *delayed* (after practice) (Wulf et al., 2010). The choice of condition is dependent on the learner; e.g. inexperienced learners of a novel task benefit from concurrent feedback whilst delaying the feedback facilitates retention in more experienced users. Essentially, these *ingredients* (practice schedule and feedback timing) have become accepted rules that support effective motor acquisition and thus, *principles* to be followed. They are accompanied by *conditions* which refer to the *parameters* involved. In the case of feedback timing, one must choose whether to deliver 'delayed' or 'concurrent' feedback. Thus, conditions often entail a 'choice' or *possible course of action* which is dependent on individual learner characteristics.

In summary:

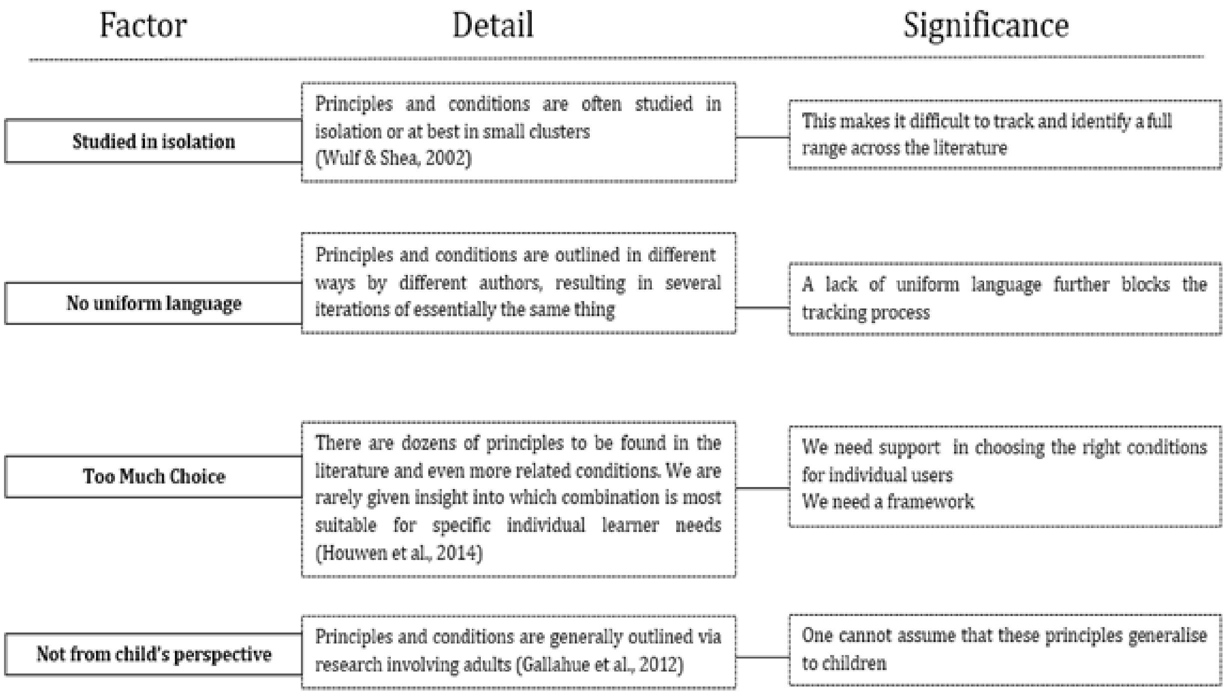
(i) **Principles** are fixed rules to be followed

(ii) They have related **conditions** that refer to the specific parameters involved

(iii) **Choice** is the possible course of action that changes from one learner to another

Despite the excellent work carried out by various researchers of motor learning theory, it appears we now have a litany of *ingredients* (principles and conditions), with too much choice and no consistent *recipe* (framework) for success. This is possibly a result of habits in current research approaches, outlined for the purpose of this study in table 2.5.

TABLE 2.5 DIFFICULTIES WITH CURRENT RESEARCH APPROACHES: FACTOR.DETAIL.SIGNIFICANCE



Factor	Detail	Significance
Studied in isolation	Principles and conditions are often studied in isolation or at best in small clusters (Wulf & Shea, 2002)	This makes it difficult to track and identify a full range across the literature
No uniform language	Principles and conditions are outlined in different ways by different authors, resulting in several iterations of essentially the same thing	A lack of uniform language further blocks the tracking process
Too Much Choice	There are dozens of principles to be found in the literature and even more related conditions. We are rarely given insight into which combination is most suitable for specific individual learner needs (Houwen et al., 2014)	We need support in choosing the right conditions for individual users We need a framework
Not from child's perspective	Principles and conditions are generally outlined via research involving adults (Gallahue et al., 2012)	One cannot assume that these principles generalise to children

In light of the challenges outlined in table 2.5, there is a definitive need to trawl through studies on motor acquisition and pull together an empirically supported list of principles and conditions. The next step is to untangle and organise them at an 'initial' level. Following this, the issue of having 'too much choice' is potentially addressed by identifying principles that are articulated in different ways but refer to the same or similar rule. It is also tackled by highlighting principles that have led to significant (empirically supported) gains and/or those most frequently found in the literature. This compilation will yield a list of ingredients from which a 'recipe' for success can be formed. Indeed, Gallahue et al., (2012) state that the first step in building a conceptual framework is to take an *inductive approach*. This begins with gathering data relating to what has already been said (specific detail) before looking for patterns (analysis) and developing a theory (generalised).

Table 2.5 Stages of an Inductive Analysis

GATHER DATA	LOOK FOR PATTERNS	DEVELOP THEORY
Specific	*Analysis*	*Generalised focus*

As such, a systematic review of the literature on gross motor training/learning was conducted in order to:

1. Gather a list of motor learning principles and conditions empirically supported by the literature
2. Look for overlap in terms of the way principles and conditions are articulated
3. Organise them into a basic structure: principal areas, principles within those areas and related conditions (first level of analysis)
4. Identify principles/conditions that appear most frequently in successful trials
5. Outline principles specific to motor learning in children

A search was conducted for papers that contained any combination of the following terms

1. Gross motor development (or motor development or locomotor development or object control development).
2. Gross motor training (or motor training or locomotor training or object control training or fundamental skills training)
3. Gross motor learning (or motor learning or locomotor learning or object control learning or fundamental skills learning)
4. Gross motor acquisition (or motor acquisition or locomotor acquisition or object control acquisition or fundamental skills acquisition)

To be included in the analysis, papers had to meet the following criteria:

1. Written in English
2. Explicitly refer to motor learning theory (or pedagogy or principles or conditions or rules)
3. Outline or reference gross motor intervention(s) or training or program(s)
4. Report statistically significant gains following intervention or training or program
5. Involve children

The electronic search resulted in more than 100 potentially relevant articles. The titles and abstracts of these articles were then reviewed against criteria for inclusion. Duplicates were also removed. Only 12 of these studies involved children and of those dozen, 7 failed to reference motor learning theory, principles, conditions, variables or rules. This low number of articles was not deemed enough to support rigorous analysis. As such, articles were reviewed again without an age specific filter. This left 33 articles that met the criteria for inclusion. From these, 18 explicitly referenced motor learning theory, principles, conditions or variables whilst the remaining papers loosely inferred a theoretical underpinning. All 33 articles were summarised but only 21 articles were deemed to meet (or nearly meet) criteria for inclusion and analysed in full. Results of the electronic search were as follows:

Reviewed	127
Excluded	94
Summarised	33
Analysed	21

FIGURE 2.5 ELECTRONIC SEARCH RESULTS

It is important to note that three of these papers provided summaries on *motor learning principles*; the most robust is, arguably, by Maas et al. (2008). Principles and conditions outlined in this study have been extracted and illustrated for the purpose of this research in table 2.6 below.

TABLE 2.6 OUTLINE OF 'SUMMARY' STUDY BY MAAS ET AL., 2008

Authors: (Summary 1) Maas et al., 2008
Description: *A critical review of principles for motor acquisition to support treatment for motor speech disorders*

(Principle)	**Conditions**	**Description**	**Effect**
Pre-Practice	• Model task • Describe task	Information about the task and its relevance	Enhances motivation and supports accurate outputs
Practice Amount	• Large • Small	The number of practice trials	Larger number of trials increase retention
Practice Distribution	• Massed • Distributed	Practice a number of trials all at the same time or over a period of time	Distributed practice enhances acquisition
Practice Variability	• Constant • Variable	Practice of the same or different targets	Repercussions for retention and transfer
Practice Schedule	• Blocked • Random	Multiple movements practiced in blocked or random trials	Can effect retention
Attentional Focus	• Internal • External	Focus on body movements (names body parts) or the movement effect (names external features)	Impacts division of attention
Feedback Type	• Knowledge of performance • Knowledge of results	How movement was performed, results of the movement	Enhances motivation and supports accurate outputs
Feedback Frequency	• High • Low	After every trial, or only some	Enhances motivation, supports accurate outputs and effects retention
Feedback Timing	• Immediate • Delayed	Provided immediately or delayed	Enhances motivation and supports accurate outputs

Whilst this summary is informative, it is not exhaustive and further analysis of the literature is required to identify a more complete list. In addition, the use of the term principle is not consistent throughout this summary paper, i.e. some *principles* are also referred to as *conditions.* Therefore, these ingredients require more consistent organisation. However, principles summarised by Maas et al. (2008) provide a useful tool with which to analyse other papers. That is, in many papers, principles/conditions are not directly stated and are more loosely *implied*. In these cases, principles can often be identified through other details. For example, Sweeting & Rink (1999) discuss the fact that feedback can be delivered in immediate or delayed fashion. These conditions are related to *Feedback Timing,* a principle not directly stated by Sweeting & Rink but detailed elsewhere in several other papers. Thus, the first objective is to identify a more exhaustive list of ingredients across the literature and to untangle principles (fixed rules) and conditions (factors involved). Later, this inductive list will be analysed for patterns informing a generalised framework. A sample 'initial analysis' is presented in table 2.7, below. Initial analysis of each paper (n=21) is outlined and illustrated in appendix 1.

TABLE 2.7 INITIAL ANALYSIS OF PAPERS THAT PROVIDE EMPIRICAL EVIDENCE FOR IMPROVED GROSS MOTOR ACQUISITION (SAMPLE)

Note: [Square brackets] indicate that principle or condition was implied/inferred not directly stated

Authors: Sweeting & Rink, 1999
Description: The effects of direct instruction on the process and product of a fundamental motor skill
Note: Focuses on the acquisition of a standing long jump, concerned with *process* and *product* of skill. Paper is also child specific

(Principle)	**Conditions**	**Description**
Learner Assessment	• Process [skill criteria] • Product [strength] • Environmental testing condition	Intervention should improve process and product e.g. jump criteria and length of jump. Both assessed at baseline prior to study. Young inexperienced users benefitted from an environmental testing condition.
[Pre-Practice]	• Physical Demonstration • Visual Demonstration	Demonstration also given via video paused on specific criteria
Practice Amount	• 60 practice trials [High or Low]	The number of practice trials in this study were high
[Practice Effort]	• Force [strength]	Task should elicit child's maximum level of force
[Practice Complexity]	• Individual parts • Whole [Parts or whole skill]	Children first practiced the initial parts of the jump, then the last part of the jump, then whole skill.
[Instructional Types]	• Direct Instruction • Demonstration • Verbal Cues	Direct Instruction is teacher lead, sets clear goals, is stepwise and sequential – includes demonstration and verbal cues
[Feedback Type]	• Knowledge of performance	Information relating to how movement was performed,
[Feedback Focus]	• Use of verbal cues	Consideration for feedback language
[Feedback Timing]	• Immediate • Delayed	Feedback given immediately or when teacher decides it is needed (observation)

Following an analysis of all 21 studies, an extensive list of 27 principles and 49 related conditions were identified. A number of these principles hold the same or similar meaning but are iterated in different ways. All iterations were tracked, recorded and organised into a basic (initial) structure of: (i) area (ii) principle and (iii) (potentially) related conditions. An inductive list is outlined in table 2.8.

Table 2.8 Inductive list of Principles and conditions for Motor Acquisition

(i) Area	**(ii) Principle (rule)**	**(iii) Condition**
Learner	Learner assessment Learner pre-test Measurement of motor skill Observational learner assessment Assessment of motor ability	• Individual Characteristics • Skill criteria • Strength/force applied • Process and/or product • Anatomical and/or physiological • Motivation • During practice or after practice
Practice	Practice Type Specificity of Practice	• Observational or Active • Physical or mental • Extension Task or Refining Task • Solo or Dyad
	Practice Challenge Practice Complexity Practice Demands [Practice Effort]	• High Effort leading to fatigue • High or low effort • Modified force • Functional difficulty versus Nominal difficulty

		• Parts and progression • Parts of the skill versus whole skill • Content development or full performance
	Practice Amount Practice Quantity	• Large or small (number of trials) • Daily or weekly • Regular or irregular • Sustained
	Practice Variability	• Constant/equal or variable • Same skill versus multi skill • Free-play versus steady
	Practice Distribution Practice Schedule	• Random versus blocked • Massed or distributed
Feedback	Feedback Type	• Knowledge of Results (KOR) versus Knowledge of Performance (KOP) • Normative or non-normative • False-positive or true reflection • Positive corrective feedback • Descriptive or prescriptive

	Feedback Composition Feedback Organisation	• Blocked or random • Frequency and timing
	Feedback Focus	• Internal or external focus
	Feedback Frequency Feedback Timing Feedback Schedule	• Immediate or delayed • Concurrent or terminal • After Successful or non-successful trials • High or low frequency • After some or all trials • Blocked or random • Bandwidth or yoked • Self-controlled or teacher controlled
Instruction	Instructional Type	• Direct instruction or mastery motivational • Demonstration and modelling • Physical/manual, visual or verbal guidance
	Instructional Timing/Schedule	• Pre-practice, concurrent or terminal
	Instructional Variability	• Constant or variable

Thus far, ‘ingredients’ for effective motor acquisition have been extracted through a systematic analysis (figure 2.4). They were originally outlined in small clusters, directly stated or implied and have therefore been pulled together in an inductive list (table 2.6). They have been organised at a first level basis in terms of *principal area, principle* and *related condition*. It is important to note that the mere presence of a principle or condition in a paper on motor acquisition does not necessarily constitute significance. Significance is determined in this study by evidence of success. One of the ways significance is potentially measured is through ‘frequency’. Put simply, if a principle/condition appears in several successful motor training programs, it is likely to be a worthwhile ingredient for success. Further, if we consider a measure of frequency to be ‘present in 5 or more studies’ (out of the 18 analysed) then a smaller number of principles and conditions are identified. In all, 11 principles and 12 conditions are stated or implied by 5 or more authors. These frequent principles and conditions were identified through a checklist analysis that tracks and records frequently occurring principles (table 2.8) and frequently occurring conditions (table 2.9). Both tables now follow with the most frequently occurring principles and conditions denoted in yellow.

√ = Principle directly stated √̲ = Principle implied

Principal Areas	ASSESSMENT				PRACTICE										FEEDBACK								INSTRUCTION		
Principles	**Learner Assessment**	**Measurement of motor skill**	**Observational Learner Assess.**	**Learner Pre-Test**	**Practice Structure**	**Practice Type**	**Specificity of Practice**	**Practice Demands**	**Practice Challenge**	**Practice Complexity**	**Practice Amount**	**Practice Variability**	**Practice Schedule**	**Practice Distribution**	**Feedback Type**	**Feedback Composition**	**Feedback Structure**	**Feedback Organisation**	**Feedback Frequency**	**Feedback Timing**	**Feedback Schedule**	**Feedback Focus**	**Instructional Type**	**Instructional Variability**	**Instructional Timing**
Badets & Blandin, 2010						√					√				√				√		√				
Broker et al., 1993			√		√̲					√̲	√̲	√̲			√̲	√							√		
Fahimi et al., 2013			√							√̲		√̲	√̲		√̲								√̲		
Fairbrother et al., 2012	√̲									√̲	√̲		√̲		√̲				√̲				√̲		
French et al., 1991										√	√	√̲											√		
Garcia & Garcia, 2006	√							√	√	√̲		√	√̲		√̲								√̲		
Goodway & Branta, '03	√								√̲	√̲	√̲				√̲							√	√̲		
Kim et al., 2012						√					√			√̲	√					√					
Lee & Porretta, 2013										√															
Lee & Schmidt, 2008											√	√		√	√				√	√					
Maas et al., 2008					√						√	√	√	√	√		√̲		√	√		√	√		√̲
Muratari et al., 2013		√					√			√̲	√̲	√̲			√̲	√							√		
Ranganathan, 2010	√											√	√	√											
Rink et al., 1992	√̲					√				√	√	√		√	√										
Sidaway et al., 2012					√					√̲		√		√	√				√	√	√				
Sweeting & Rink, 1999	√									√̲	√̲				√				√̲			√̲	√	√̲	
Theeboom et al., 1995	√									√̲		√̲			√							√̲	√̲		
Wulf & Shea, 2002													√	√			√	√	√	√		√	√̲		
Wulf et al., 2010					√̲										√				√	√		√	√̲		
Wulf, 1991	√̲		√									√̲			√̲										
Wulf, Shea et al., '10				√		√̲						√	√		√				√	√	√		√		

✓ = Condition directly stated

✓̲ = Condition implied

Principal Areas	**Asses. Parameters**						**Practice Conditions**												**Feedback Conditions**													**Instruction Conditions**				
Conditions	**Criteria (Process)**	**Force /effort/strength (Product)**	**Performance/Developmental Stage**	**Activity Level /Energy Expenditure**	**Anatomical/Physiological Makeup**	**Motivation (verbal/physical assent)**	**Observational /Mental or Physical**	**Extension Task or Refining Task**	**Solo or Dyad**	**Modified Force/Modified Criteria**	**High or Low Effort/Force**	**Functional Diff. versus Nominal Diff.**	**Parts and Progression**	**Same Skill versus multi skills**	**Random versus Blocked**	**High v. Low number of Trials**	**Massed versus Distributed**	**Constant versus Variable**	**Knowledge of Results**	**Knowledge of Performance**	**Descriptive V Prescriptive**	**False Positive versus true reflection**	**Normative versus non normative**	**Blocked or Random**	**Internal versus External Focus**	**After successful or unsuccessful trials**	**Concurrent versus Terminal**	**Immediate versus Delayed**	**Self-Controlled or Teacher Controlled**	**High versus Low Frequency**	**Frequent versus Reduced**	**Physical or verbal Demonstration**	**Direct Instruction**	**Mastery Motivational**	**Pre-Practice, concurrent or terminal**	**Constant or Variable**
Badets &Blandin, 2010							✓									✓			✓	✓				✓						✓						
Branta & Goodway 03			✓			✓					✓̲	✓̲				✓			✓̲	✓̲					✓					✓		✓	✓			
Broker et al.,1993	✓̲	✓									✓̲		✓̲			✓̲		✓̲	✓̲	✓̲							✓	✓				✓	✓̲			
Fahimi et al., 2013			✓									✓̲				✓̲																	✓̲			
Fairbrother et al., 2012				✓							✓				✓	✓̲			✓										✓	✓						
French et al., 1991											✓		✓			✓		✓̲														✓				
Garcia & Garcia, 2006					✓						✓		✓̲		✓̲			✓̲	✓̲	✓̲												✓	✓			
Kim et al., 2012								✓							✓	✓			✓	✓							✓									
Lee & Porretta, 2013										✓̲	✓̲	✓̲																								
Lee & Schmidt, 2008															✓	✓		✓	✓	✓							✓			✓						
Maas et al., 2008															✓	✓	✓	✓	✓	✓					✓			✓		✓		✓̲	✓̲		✓	
Muratari et al., 2013													✓			✓		✓	✓	✓	✓				✓			✓̲				✓				
Ranganathan et al., '10	✓̲	✓													✓		✓	✓																		
Rink et al., 1992	✓							✓					✓		✓	✓̲			✓	✓																
Sidaway, 2012	✓̲											✓			✓			✓	✓	✓							✓									
Sweeting & Rink, 1999	✓	✓									✓̲		✓			✓				✓					✓̲			✓				✓				
Theeboom et al., 1995						✓					✓							✓					✓		✓									✓		
Wulf & Shea, 2002															✓		✓							✓̲	✓					✓	✓					
Wulf, Shea et al., 2010									✓											✓		✓	✓		✓	✓			✓		✓	✓			✓	
Wulf et al., 2010		✓													✓	✓							✓		✓			✓		✓		✓			✓	
Wulf, 1991											✓̲							✓	✓	✓̲						✓		✓		✓̲	✓	✓			✓	

Overall, a number of frequently occurring principles and conditions can be identified following a checklist analysis across 21 studies. Whilst this 'frequency' implies importance, other principles/conditions cannot simply be ignored just because they are less referenced across the literature. Further, some principles and conditions are so closely linked they could potentially be clustered under the one rule whilst others have been articulated in different ways but hold the same or similar meaning. Effectively, a second stage of analysis is required to explore these additional patterns and transform a set of ingredients (for effective motor acquisition) into a recipe, or *framework,* for success. This will take place in chapter 3.

2.9 CONCLUSION

Poor locomotor performance in children is linked with obesity, low self-esteem, low social confidence, mental health problems and cognitive difficulties which affect mathematics and reading. Conversely, the majority of modern children demonstrate poor locomotor skills and do not perform with proficient 'criteria'. This is attributed to increased sedentary play habits such as online interactions and video game play. However, 3D sensor control systems have triggered a shift in gameplay and game design. Popular exergames call for gross motor simulated interactivity and gross motor outputs from the user. These types of video games have been utilised by teachers/instructors/clinicians to support the training of sports related skills (including object control skills), to increase physical fitness, improve balance, strength and co-ordination. They have also been used for the rehabilitation of basic gross motor movement in elderly stroke patients.

However, 3D sensor accuracy is particularly poor when it comes to measuring locomotor outputs owing to the difficulty capturing user motion in the lower limbs. Consequently, there are a limited number of video games on the market that call upon the user to hop, skip, jump or slide. Further, none of these games are purposely designed to target locomotor acquisition. Of the games that are on offer, users typically cheat their outputs to limit energy expenditure, reducing a 'jump' to a basic arm lift by moving closer to the sensor. Technical limitations are potentially negotiated with the aid of an additional component, the teacher, who pre-empts and prevents cheated outputs by providing direct instruction and feedback that the game does not. The teacher also has the capacity to adapt game features including timers, targets and score systems to meet individual user needs. However, video games currently on the market are technically 'locked in' and do not allow for this hypothetical adaptive process. Thus, a set of purpose built video games with adaptable design features are required.

In order to ensure that these games support locomotor acquisition, they also require an underpinning principled *design.* A principled framework could be utilised to inform both game design (informing the types of design features required) and game deployment (i.e. how game features should be adapted, essentially, what the teacher needs to do during this ‘adaptive process’). Such a framework is currently absent from the literature. Consequently, the first steps towards its formation were taken in section 2.8, with a systematic analysis of the literature resulting in the outline of an inductive list of principles and conditions that best support motor training and acquisition. The following chapter aims to build upon findings from this state of the art and take the next steps towards a generalised ‘principled’ framework. Once this framework has been outlined, it will be utilised to inform the design, development and deployment of video games for locomotor acquisition in the classroom; potentially transforming a barrier to locomotor acquisition into an effective training ground.

3 DESIGN

3.1 INTRODUCTION

This chapter is concerned with the design of a principled framework that can be utilised to best support locomotor acquisition and underpin virtual (or indeed, non-virtual) motor training programs. The framework is informed by a systematic analysis of (i) literature on motor learning theory and (ii) empirically supported studies on motor training and acquisition. An initial stage of analysis took place in section 2.8, resulting in an inductive list of principles and conditions empirically supported to improve gross motor acquisition. Principles and conditions most frequently discussed across the literature were also identified. This chapter examines this inductive list for patterns beyond frequency. It aims to bring a uniformity of language, limit the amount of choice (by clustering closely related principles/conditions) and support the decision making process around which combination of principles and conditions best support individual learner needs. In this thesis, the framework is specifically intended to underpin the design, development, deployment and evaluation of video games for locomotor acquisition in the classroom setting.

3.2 A PRINCIPLED DESIGN FRAMEWORK: SECOND STEP

Principles and conditions for successful motor acquisition are often studied and outlined in isolation or small clusters across the literature. Consequently, a large number of principles and conditions have been identified as having a positive impact on locomotor acquisition independent of one another. The difficulty lies in identifying those principles and conditions that *best* support locomotor acquisition and crucially, the best combination of principles and conditions that are most likely to facilitate effective gains (Gallahue et al., 2012; Houwen et al., 2014). This represents the next stage of analysis and begins by limiting the amount of choice. That is, with a litany of principles and conditions demonstrating successful motor gains, instructors/teachers are overwhelmed with too much choice. This issue is potentially negotiated by identifying patterns. First, by bringing a uniformity to the language e.g. principles/conditions that hold the same or similar meaning but are articulated in different ways. Then, by potentially clustering closely related principles under one over-arching rule and lastly by providing a rubric to support with the decision making process around which combination of principles and conditions best support individual learner needs.

Supporting the decision making process for individual learners is a daunting task because every learner is so different. This process is first tackled at a macro level by highlighting appropriate conditions for a *novice* learner (typically children aged 4-6 years) and then highlighting potential best practice for more *experienced* learners. However, the appropriate combination of principles and conditions within these subsets (novice or experienced) varies further depending on individual characteristics (Schmidt & Lee, 2005; Gabbard, 2008; Logan et al., 2012). Thus, it is crucial to 'know' the learner, and whilst several authors acknowledge the importance of a baseline learner assessment, to date, this assessment process has typically been ignored. When assessment is considered, it generally focuses on diagnostic not prescriptive characteristics. For example, popular assessment tools such as TGMD-2 (Ulrich, 2000) focus solely on the *process* of performing locomotor skills, i.e. what criteria the learner can/cannot perform. However, in order to determine appropriate conditions for individual learners, we also need to assess the *product* of locomotor performance i.e. how high they can jump, and/or how many jumps they can perform before becoming fatigued. This information speaks to the conditions (or factors) of practice that will best support the individual learner. Accordingly, a principled framework for motor acquisition aims to include:

- **Uniformity of language** brought to principles (rules) and conditions (factors) of motor acquisition
- A controlled **amount of choice** in terms of what principles and conditions support effective acquisition
- A **learner assessment** with results informing the **decision making process** around which combination of principles and conditions best support individual learner needs

As a starting point of this analysis, empirically supported principles and conditions for motor acquisition outlined in section 2.4 are compiled and organised in terms of related *area*; (i) *practice, (ii) feedback, (iii) instruction* and *(iv) learner.* Each area is now examined in isolation and analysed in a deductive process.

3.2.1 PRACTICE

Practice of motor skills creates a ‘perceptual trace’ or *motor memory* that facilitates motor performance (Lee & Schmidt, 2008). Effective motor skills denote effective motor memory structures which can only be constructed with practice. That is, practice in the right *conditions* (Adams & Bray, 1970). Essentially, practice conditions should not merely promote short term improvements but also facilitate lasting change and retention (Schmidt & Bjork, 1992). Principles and conditions related to practice are often reduced to the ‘number of practice trials’ and the ‘amount of time spent practicing’ (Rink et al., 1992). However, effective motor memory structures can only be fostered with effective practice structures.

A significant number of principles and conditions relating to practice were identified across the literature and outlined in section 2.4. A summary of these principles and conditions now follows. They are initially structured like so:

- Practice principles are matched with their related practice conditions
- Frequently occurring principles are denoted in bold
- Multiple iterations of the same principles and conditions are outlined in brackets
- The first articulation is generally retained with variations also recorded but marked with a ~~strike~~

TABLE 3.1 PRINCIPAL AREA ANALYSIS: PRACTICE

Principle	Conditions	Notes
Practice Type ~~(or types of practice)~~	Physical~~ (or active)~~, observational, mental ~~(or cognitive)~~ Solo or Dyad	Practice generally involves physical activity but can also benefit from observational and mental rehearsal. Practice can also be solo, in pairs or small groups
Practice specificity ~~(or specificity of practice)~~	Deliberate or self generated ~~(intentional or unintentional)~~	Deliberate practice with specific practice goals is essential to improve motor acquisition in children.
Practice Amount (~~practice quantity, number of practice trials)~~	**Large amounts or smaller amount of trials** ~~(low number or high number of trials) (daily practice) (sustained practice) (Regular or irregular practice)~~	Refers to the number of practice trials. Generally, a high number of practice trials improve skills and lock motor memory structure. Dependent on crucial interactions and conditions relating to variability, distribution and complexity
Practice Distribution	**Massed practice or distributed practice**	Refers to time e.g. a number of practice trials over a short space of time or the same number of trials over a longer period of time
[Practice Effort] ~~(practice challenge, practice exertion)~~	**High or low effort** ~~(High Effort Leading to Fatigue) (functional difficulty versus nominal difficulty) (Challenges at own level) (modified force)~~	Practice should push the learner but not to the point of exhaustion or learner will not return to task. Challenge interacts with motivation, complexity, schedule, amount and distribution.
Practice Complexity (~~practice difficulty, practice demands)~~	**Whole skill or parts of skill** ~~(Simple or complex) (Extension task or refining task) (parts and progression) (Content development or whole skill)~~	Where a skill has many components, it may be best to make it less complex by focusing on parts of the skill (content development/extension task) before advancing to whole skill (refining task)
Practice Variability ~~(practice schedule, practice target, practice goal)~~	**Constant or Variable** ~~(constant or variable) (Same or different) (bandwidth or yoked) (Stay or change)~~	Refers to practice of the same constant target or practice of multiple variable targets. Constant practice can improve acquisition but stifle retention and motivation. Interacts with complexity, where parts and progression may also constitute variability
Practice Schedule ~~(Practice timetable)~~	**Blocked or Random** ~~(Distribution an variability)~~	Practicing the same target in a block, or multiple targets at random. Principle is heavily interlinked with variability and amount. Few studies have investigated the effects of either condition on motor acquisition

A large volume of work produced in the 1950's and 1960's (see: Bourne & Archer, 1956) was concerned with the most effective ways to distribute practice**.** This 'practice distribution' refers to the time or *spacing* between practice trials. In essence, a number of practice trials may be *massed* over a short period of time or *distributed* over a longer period of time. Initially, it was deemed that massed practice lead to significant gains but later reported that distributed practice trials facilitated more long term effects (Lee & Schmidt, 2008). If practice is intended to facilitate motor memory structures, then it would appear distributed trials afford the learner more time and space to create these long lasting pathways. In the 1970's, a number of authors became interested in the affect that 'practice variability' would have on motor acquisition. Variability is concerned with the *focus* of practice trials, e.g. *constant* practice on the same skill or *variable* practice of different skills. Findings were described as counter-intuitive (Shea & Morgan, 1979). Indeed, views on memory presented by Adams (1971) suggest that a constant practice of the same skill benefits motor learning. However, Shea & Morgan (1979) found that constant practice of the same skill demonstrated gains at task performance (during practice) but variable practice initiated longer lasting effects. This was supported by Battig (1979) amongst others. Interestingly, practice distribution and variability are both interlinked with the *amount* of practice trials (e.g. high or low number) within a practice session. 'Practice amount' is thus, a principle of motor learning referenced frequently across the literature (Rink et al., 1992; Maas et al., 2008; Lee & Schmidt, 2008). Ultimately, learners benefit from beginning with a low number of trials progressing to a higher number of trials over time (Park & Shea, 2005; Maas et al., 2008).

A number of authors refer to a 'practice schedule' (or timetable) in much the same way as practice variability. Essentially, constant or variable practice conditions are discussed with different vocabulary i.e. *blocked* or *random* practice trials (Wulf & Shea, 2002). Conversely, several authors refer to a practice schedule in a way that's similar to practice distribution. For example, constant or variable targets are also referenced as blocked or random targets by Maas et al., (2008). Ultimately, Ranganathan and Newell (2010) state that a 'practice schedule' has several dimensions including distribution and variability. This explains the overlap across the literature and provides an impetus to cluster several principles under one overarching rule. A schedule outlines 'things to be done showing the times or dates when they are intended to happen' (Cambridge Dictionary, 2016). It brings a crucial 'structure' to practice. Ergo, **Structured Practice** presents as a principle to be adhered to and involves a choice of conditions relating to amount, variability and distribution. These conditions include: a *high or low* number of *constant or variable* targets, that are *massed* or *distributed* over a period of time. A **structured practice** aligns with characteristics of the individual learner and does not push past baseline capabilities. For example, too many trials or the constant practice of a target that the learner is incapable of performing could prove too much of a ‘challenge’. This can stifle motivation and prevent future ‘efforts’.

In relation to ‘practice challenge’ and ‘practice effort’, both parameters could also be described as interrelated principles. In addition, both are frequently referenced across the literature. We know that practice should elicit a high amount of effort resulting in fatigue (Schmidt & Wrisberg, 1993; Day, 2010; Gram et al., 2012). Indeed, there is very little benefit to practice unless it is intense (Day, 2010). Furthermore, this intensity is most often determined by fitness level or ‘energy expenditure’ (Fairbrother et al., 2012). Thus, if a learner can jump ten times in one minute before presenting as fatigued, then that same learner will likely give up if asked to jump twenty times in the same timeframe. Similarly, effort is also described by several authors, including Wulf (1991), in terms of ‘force’ i.e. the height, direction or speed of an output (product). This means a learner should not be asked to jump to a height beyond their reach. In short, practice effort is seemingly determined by the *fitness* level of the learner and the *force* of their outputs. It should be noted that several studies appear to interchange the term *effort* with *challenge*. However, ‘challenge’ literally refers to ‘a competitive situation’ (Cambridge Dictionary, 2016). Whilst practice may be structured to facilitate a competitive component, this is not always the case nor a pre-requisite. In contrast, ‘effort’ refers to ‘a vigorous attempt’ thus, encompassing both competitive or more intrinsic practice structures.

A final frequently referenced principle across the literature is ‘practice complexity’. If practice effort is more concerned with the *product* of performance then practice complexity is largely discussed in terms of the process, i.e. skill criteria. Evidence suggests that complex motor skills should initially be worked on in *parts and progression* as opposed to a *whole skill* performance. Furthermore, Rink et al. (1992) remind us that when practice is adapted to work on parts and progression, it is referred to as an *extension task.* On the other hand, a task that focuses on practice of a whole skill is called a *refining task*. The complexity of a task should be relative to the individual learner and balance what Guadagnoly & Lee (2004) describe as *Nominal Difficulty* (the characteristics/complexity of the skill) with *Functional Difficulty* (actual skill level of the learner). One could suggest that owing to their cognitive development stage, most children will find the acquisition of locomotor skills complex and should therefore initially tackle these skills in parts and progression before focusing on refinement through whole skill performance. However, a child who demonstrates high processing capabilities is potentially best served focusing on parts of a skill within a whole skill practice. This fosters self-correction and intrinsic motivation (Rink et al., 1992).

It should be noted that Fairbrother et al. (2012) also discuss *energy expenditure* in relation to practice complexity. That is, the complexity of a practice trial may also be determined by the energy expenditure required from the learner. This implies that practice complexity is not only determined by the *process* (e.g. skill criteria) but also by product (e.g. fitness/energy and force). Crucially, this provides an impetus to cluster ‘Practice Complexity’ (concerned with skill process) and ‘Practice Effort’ (concerned with product) under a single heading. Thus an over-arching principle of **High Effort Practice** presents as a rule to be adhered to. This principle aims to elicit high effort that is in line with the learner’s criteria level determining if a skill should be worked on in *parts and progression* or *whole skill;* as well as a learner’s *fitness and force* capabilities, determining the number, height, length and speed of outputs.

Of the remaining principles identified across the literature, the ‘type of practice’ may well present as an important consideration in the future with more robust evidence to support motor practice beyond physical activity (e.g. mental/cognitive rehearsal). However, at present, evidence to support their worth is lacking. Conversely, there is evidence to highlight the positive affect of practice involving others, in dyads or small groups, from time to time (Wulf, Shea & Lewthwaite, 2010). Moving from solo practice to paired practice would seemingly constitute ‘variability’ and could be clustered as such. With that, principles and conditions relating to practice have been reduced to the following (figure 3.2, below):

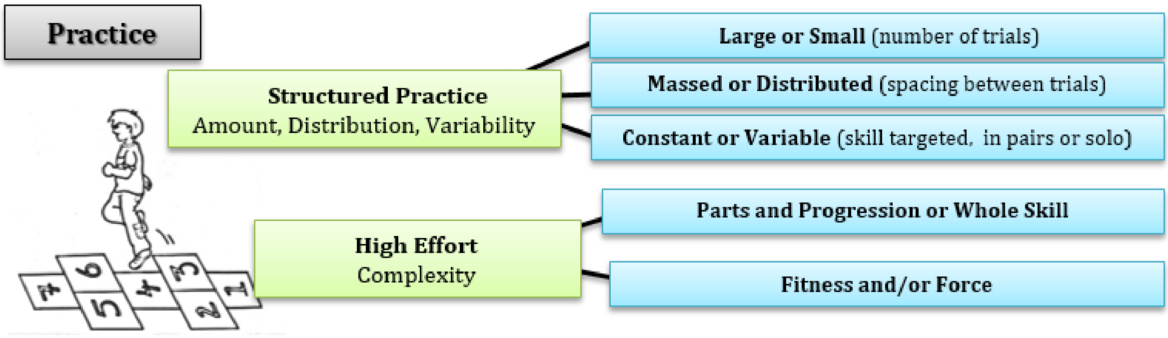


FIGURE 3.1 PRINCIPLES AND CONDITIONS RELATING TO PRACTICE

3.2.2 FEEDBACK

Research has investigated the effects that feedback has on motor acquisition for several decades (incl. Adams 1968; Schmidt, 1975). There is consensus that feedback is crucial for effective acquisition. However, feedback can also be detrimental to acquisition unless it is delivered in the right way, under the right conditions. A summary of principles and conditions relating to feedback (identified in the literature and outlined in section 2.4) follows. This summary has the following structure:

- Principles are paired with their related conditions
- Frequently occurring principles are denoted in bold
- Multiple iterations of the same principles and conditions are outlined in brackets
- The first articulation is retained with variations marked with a ~~strike~~

TABLE 3.2 PRINCIPAL AREA ANALYSIS: FEEDBACK

Principle	Conditions	Notes
Feedback Type **~~(types of feedback)~~**	**Knowledge of Results or Knowledge of Performance Or Normative Feedback**	KOR – information about practice success KOP – information about practice performance Normative Feedback- your performance relative to peers
Feedback Composition ~~(feedback organisation, feedback structure)~~	**Self-Controlled feedback or Teacher controlled** Descriptive or Prescriptive	Describes the results of a performance, prescribes what needs to happen next. Very much linked with KOP and KOR, both descriptive and precriptive feedback are often intuitively provided by an educator
Feedback Frequency ~~(Feedback amount, Feedback quantity)~~	**High or low feedback frequency:**	During/after every performance or only on some attempts Frequent feedback can optimize the learning of complex skills, but it can also have a degrading quality where learners become too dependent on KOR and KOP
Feedback Timing (~~feedback schedule)~~	**Immediate or delayed** **~~(Concurrent or terminal) (before, during, after)~~** **Self-Controlled feedback or Teacher controlled**	Feedback can be delivered during practice or after practice. Very much linked with frequency. There is evidence to suggest that delayed feedback can facilitate more long lasting pathways and support retention. Self-controlled feedback proves useful in adults
Attentional Focus	**External or internal** **~~(movement effect or movement form)~~**	Refer to the actual movement (reference body parts) or to the movement effect not mention of body parts. Evidence suggests an internal focus divides attention and slows down the motor learning process
Feedback Schedule	Blocked or Random (Frequency, timing)	Blocked feedback can focus on the same KOR or KOP, whereas random feedback can refer to different performance characteristics. Strongly linked to feedback frequency, timing and composition.

For several decades, Prof. Gabriele Wulf has carried out research into the effects of feedback on motor acquisition. As a result of her work and other experts in the field, there is a litany of empirical evidence to support various principles and conditions related to feedback that best support effective motor acquisition.

First, there are several *types* of feedback. For example, *Knowledge of Performance* (KoP) alerts the learner to errors in performance allowing them to adjust accordingly. KoP is largely concerned with 'process' and provides information about how a skill should be performed relative to how the learner just performed (Sidaway et al., 2012; Gram, 2012; Schmidt and Wrisberg, 2008). In contrast, *Knowledge of Results* (KoR) is more focused on the 'product' or result of performance. This feedback type interacts dynamically with KoP to provide information relating to the overall success of a practice trial. KoR can be utilised to motivate the learner and increase confidence (Wulf, Shea & Lewthwaite, 2010). Both of the aforementioned feedback types are heavily linked to what several authors refer to as 'feedback composition' i.e. feedback that is *prescriptive* or *descriptive* (Muratari et al., 2013). Indeed, KoP and KoR could each be described as prescriptive and descriptive, respectively. Consequently, these feedback types can be clustered under 'feedback composition'.

'Normative Feedback' presents as another type of feedback outlined in the literature. It refers to a learner's need to feel at least as competent as their peers. This has a significant bearing on motivation. Normative feedback can be facilitated through task differentiation and the provision of *false-positives*; i.e. false feedback that misleads the learner into thinking they are better than their current level and/or just as good as their peers (Lewthwaite & Wulf, 2010). All types of feedback are empirically supported across the literature. This paves the way for a **Multi Feedback Approach** with the choice of providing prescriptive (KOP), descriptive (KOR) or normative feedback conditions.

A dynamically related principle of 'attentional focus' appears in the literature as having a significant affect on motor acquisition. This principle refers to the language used when providing feedback (of any type). *An internal focus* (or movement form) involves the use of language that refers to specific body parts such as, "lift your arms", and can slow down the learning process as it causes a division of attention. In contrast, *an external focus* (or movement effect), e.g. "reach up to the net", elicits the same physical response as "lift your arms" but entails less cognitive demand. This speeds up the learning process and supports retention.

The 'frequency' with which feedback is deployed has also been discussed by several authors. Feedback frequency refers to how often feedback is delivered. Results from Sidaway et al., (2012) suggest that feedback frequency is dependent on the *task complexity.* The study specifically relates to children (although, the cohort at aged ten are at the latter end of the developmental period) and findings indicate that, for the most part, children should receive high feedback frequency. However, reduced feedback is also advocated for children with high cognitive functioning skills. Essentially, low feedback frequency for high functioning children supports retention, motivation and helps to foster intrinsic feedback strategies such as error detection and self-correction (Kim et al., 2012).

Overall, the 'frequency' and 'focus' of feedback are identified in the literature as inter-related and dynamic. Wulf et al., (2010) provide robust evidence to suggest that feedback with an external focus after every trial supports significantly improved acquisition and retention. In contrast, several authors found that feedback (with an internal focus) after every trial supports acquisition during practice but not away from it (Maas et al., 2008; Sidaway et al., 2012). Thus, it appears that feedback given with an external focus, should be frequently provided after every trial. In contrast, feedback that has an internal focus and references the parts of the body, should be given less frequently, after every *other* trial. Note that in both scenarios, feedback is specifically delivered 'after' a trial. This *timing* with which feedback is delivered also presents as another principle to be considered.

Feedback timing refers to the provision of 'terminal feedback' (delivered after a trial) or 'concurrent feedback' (delivered during a trial). Schmidt and Wolf (1992) found that concurrent feedback best supports effective acquisition and in particular, the transference of the skill from practice to real life. These findings were supported by Swinnen et al., (1996). However, concurrent feedback is only effective if there is enough time for the learner to process the information allowing them to make relevant adjustments. There is also some research into the positive affect self-controlled feedback has on learner performance. That is, the learner receives feedback only when they ask for it. Self-controlled feedback has demonstrated positive results with adult learners but not yet children. This is understandable since adults are more capable of self-evaluation and are more aware that there is something to be learned. However, the likelihood is that children with high-cognitive functioning may also benefit from this additional condition.

Overall, 'feedback timing', 'feedback frequency' and 'attentional focus' are variables that *structure* the way feedback is delivered. This mean an overarching principle of **Structured Feedback** could be framed by the *frequency, timing* and *focus* of feedback, and interrelated conditions. Ultimately, effective feedback for motor acquisition takes a **Multi Feedback Approach** with KOR, KOP and/or Normative feedback types, each one 'structured' with high or low frequency, an internal or external focus, and imparted during or after practice trials. Novice learners benefit from multiple feedback types, with frequent KoR during task performance and KoP following every trial or every other trial. Normative feedback and false positives can be utilised to maintain interest and motivation over a period of time. Feedback should also be delivered less frequently as a learner improves their performance. This supports self-correction, transference and retention. Principles and conditions relating to feedback have thus, been reduced to the following (figure 3.3):

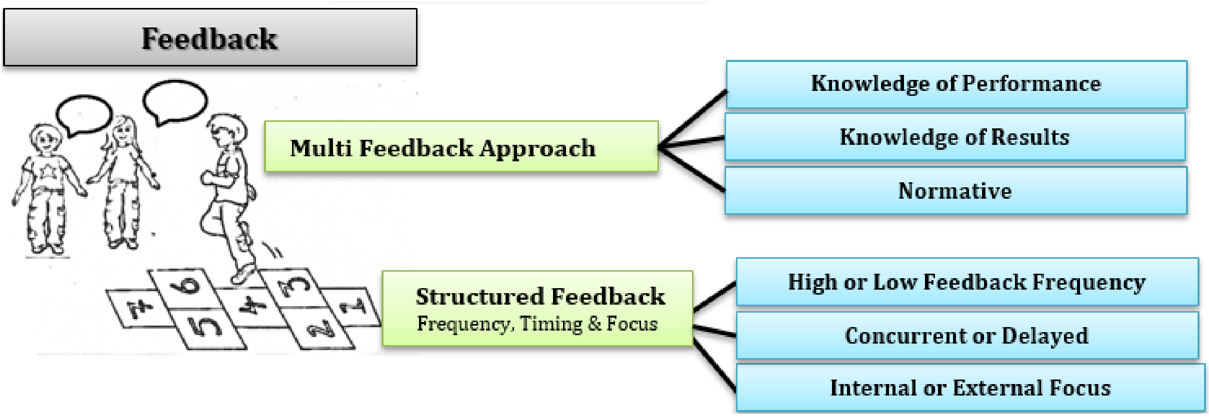


FIGURE 3.2 PRINCIPLES AND CONDITIONS RELATING TO FEEDBACK

3.2.3 INSTRUCTION

Effective acquisition of gross motor skills is reliant on the provision of adequate and effective *instruction* (Sweeting & Rink, 1999; Schmidt & Lee, 2005, Wulf et al., 2009; Gallahue et al., 2012). Principles and conditions related to instruction are particularly dynamic and often difficult to untangle from prescriptive feedback such as knowledge of performance, which describes the learner's performance, and instructs them on how to improve. A summary of instructional principles and conditions deciphered in the literature and outlined in section 2.4 will now follow. Once again:

- Principles have been matched with related conditions
- Frequently occurring principles are denoted in bold
- Multiple iterations of the same/similar principles and conditions are outlined in brackets
- The first articulation is retained with repeats marked with a ~~strike~~.

TABLE 3.3 PRINCIPAL AREA ANALYSIS: INSTRUCTION

Principle	Conditions	Notes
Instructional Type **~~(types of instruction)~~**	**Direct instruction – teacher lead** **Mastery motivational - learner lead** **Or Guidance procedures** ~~(physical, manual, visual or verbal guidance)~~	Direct instruction is particularly successful for younger learners of a novice task. Mastery motivational instruction is more learner lead and suitable for the more experienced and proficient learners. Guidance procedures such as modelling and demonstration increase the rate of acquisition, particularly for novice learners and visual learners.
Instructional Timing ~~Instructional schedule~~	Pre — practice, concurrent or terminal ~~Before, during or after trials~~	Timing is a common variable that distinguishes between certain types of instruction, pre-practice guidance procedures (before) or direct instruction (during practice) or knowledge of performance (after).
Instructional Delivery ~~(delivery of instruction)~~	Verbal or physical instruction	Instruction benefits from both verbal and physical demonstrations depending on the individual learners
Instructional Distribution	Massed or distributed	Instruction can be massed (generally for novice learners), or distributed. Distribution could refer to the reduction of instruction over time, which has been found to support retention.

From an instructional standpoint, empirical evidence supports a **Multi Instructional Approach** in order to facilitate effective motor learning gains. *Direct* Instruction presents as the most frequently referenced *'type of instruction'* across the literature. It refers to instruction that is teacher lead and provides clear, explicit descriptions of a skill. This 'explicit' instructional type is particularly important for novice learners (Tuovinen & Sweller, 1999). Furthermore, the modern day child demonstrates such poor locomotor skills because self-generated play habits no longer facilitate acquisition. Thus, direct instruction is particularly important to transform self-generated play habits from which learning is incidental into what Ericsson (1993) describes as *deliberate practice* where learning is purposeful. Whilst direct instruction is teacher lead, it can be balanced by fostering a 'mastery motivational' climate which affords the learner more choice during task selection (Ames, 1992; Theeboom et al., 1995). *A Mastery Motivational Climate* increases motivation and facilitates longer periods of practice and interest.

Effective motor skill acquisition is also reliant on the provision of 'guidance procedures' mainly to adequately prepare the learner for a task (Schmidt & Lee, 2005). Guidance procedures typically involve demonstration presented at pre-practice stage (Maas et al., 2008). There is systematic evidence to support the delivery of this instructional type in two ways. Firstly, 'verbal demonstration' supports aural learners (McNeil, Doyle & Wambaugh, 2000; Sweeting & Rink, 1996) (e.g. jump 10 times in one minute) whilst 'physical demonstration' (or modelling) allows visual learners to see how a task should be performed (Wulf, Shea, & Lewthwaite, 2000). Thus, a **Multi Instructional Approach** constitutes a principle to be adhered to. It includes the provision of 'direct or mastery motivational instruction' and 'verbal or physical demonstration'.

As was the case for practice and feedback, a multi instructional approach requires **structure**. The importance of structure can initially be inferred by multiple references across the literature to a specific 'pre-practice' demonstration (Maas et al., 2008; Wulf et al., 2010). This specificity of *pre-practice* (as opposed to concurrent or terminal) could constitute 'instructional timing'. Interestingly, demonstration delivered after practice (as opposed to pre-practice) is hard to differentiate from KoP/feedback. Pre-practice demonstration generally offers no comparison to previous performance and instead, offers explicit instruction on a task. In contrast, terminal demonstration would likely refer to a performance just given. This effectively constitutes KoP/feedback. Thus, instruction and feedback are largely separated by the 'timing' of delivery.

Beyond instructional timing, it appears the way instruction is 'distributed' (massed or distributed) can also have significant effect. That is, multi instructional techniques are often best 'massed' in order to support novice learners with the acquisition of complex skills. However, this instruction should be reduced and thus, 'distributed' over time to support more long lasting pathways (retention). Essentially, 'timing' (pre-practice, concurrent or terminal) and 'distribution' (massed or distributed) are variables to be considered for instruction. As previously stated, Ranganathan and Newell (2010) refer to a ‘practice schedule’ as having several dimensions including distribution and variability, both of which are concerned with timing. Thus an instructional schedule could consider these parameters and prompt a choice of conditions relating to pre, concurrent or terminal instruction, that is massed, distributed or even reduced over time. Overall, there is evidence in the literature to suggest that novice learners benefit from demonstrations before every trial (or every other trial) with direct instruction that is delivered n concurrent fashion. Additionally, a mastery motivational climates helps maintain interest and motivation (Maas et al., 2008; Ames, 1992). This motivational climate is effectively supported by variability of instruction, including the reduction of demonstration and direct instruction over time, leading to more lasting effects. Principles and conditions relating to instruction could ultimately constitute the following (figure 3.4):

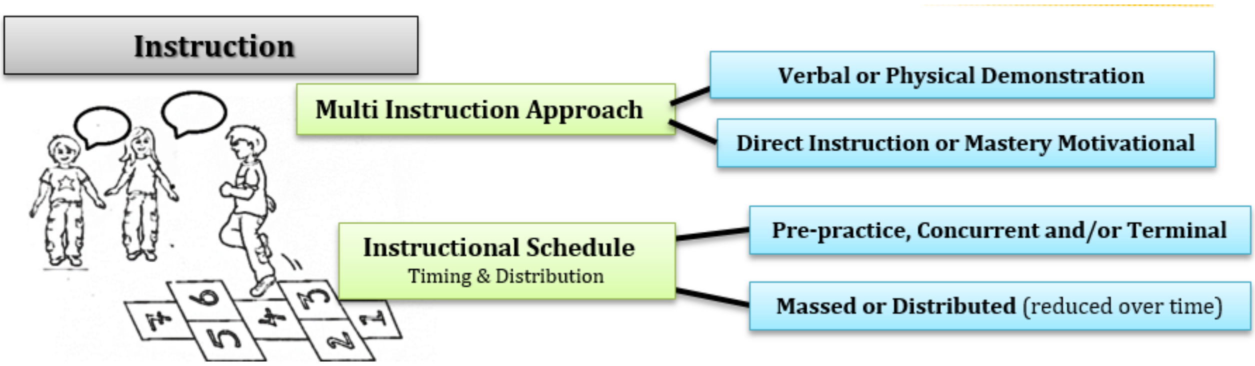


FIGURE 3.3 PRINCIPLES AND CONDITIONS RELATING TO INSTRUCTION

Thus far, principles have been identified and deduced from systematic analysis of the literature and relate to practice, feedback and instruction. These principles are fixed and should be adhered to for all users. However, the factors involved, their conditions, are dependent on individual learner needs. It is therefore crucial to provide insight into what constitutes the most appropriate *combination of conditions* to meet individual learner needs (Gallahue et al., 2012; Houwen et al., 2014). This decision making process requires an understanding of learner characteristics.

3.2.4 LEARNER

In section 2.4, multiple principles relating to the learner were outlined, most of which had the same meaning. In essence, more than ten studies referred to a learner assessment or variations thereupon. Iterations included: analysis of performance level, measurement of performance, measurement of motor skill. Where assessment was mentioned, it was largely focused on the process of performance. Put simply, researchers wanted to know if their cohort could perform accurate skill criteria and if they made improvements from pretest to posttest. However, four studies also referenced (to some extent) an assessment of the performance (Broker et al., 1993; Sweeting & Rink, 1999; Ranganathan et al., 2010; Wulf et al., 2010). This assessment was largely focused on the product of the skills, i.e. how high the user could jump, or how far they could throw. One study also referred to a measurement of the user's 'energy expenditure' (Fairbrother et al., 2012). This study highlights the importance of identifying the learner's point of fatigue and notes it as variable that can be utilised to inform appropriate task/practice complexity. Finally, whilst the assessment of learner motivation is referenced across the literature, it is interesting to note that Theeboom et al. (1995) directly assess this parameter through questioning and ask for verbal assent before practice. Essentially, if motivation is observed to be lacking or indeed, if verbal assent is not given, several conditions relating to practice, feedback and/or instruction can be adapted to encourage the learner further. The over-arching point is that whilst every user is different, there are only a number of parameters (or characteristics) that need to be assessed in order to distinguish one learner from another. A summary of learner parameters to assess, identified in the literature, is outlined below (table 3.4).

TABLE 3.4 PRINCIPAL AREA ANALYSIS: LEARNER

Principle	Parameters to Assess	Notes
Learner Assessment ~~*Or observational learner assessment*~~ ~~**or**~~ ~~*Analysis of performance level*~~ ~~**or**~~ ~~*Assessment of learner characteristics*~~ ~~**or**~~ ~~*measurement of motor skill*~~	**Assess Performance Process** Skill Criteria	Motor assessment is outcome oriented and identifies the skill criteria (if any) learners are already capable of performing
	Assess motivational levels	Attain Verbal Assent to Attend task: Learner states that they do or do not wish to practice
	Assess Performance Product Force/strength of output	Identifies the strength or force of a learner's output e.g. how far they can throw, how high they can jump
	Energy expenditure	Identifies a learners point of fatigue

Whilst *Learner assessment* is articulated in different ways across different studies, most references point towards a *process oriented* approach. This approach is focused on identifying skill deficits (Barnett et al., 2013). Indeed, standardised locomotor assessment tools are also process oriented and interested in how the learner performs a skill, specifically, what criteria are present/absent. This kind of assessment is usually diagnostic and carried out in order to identify the learner's developmental stage and/or skill level, e.g. novice or expert. However, in order to support an appropriate practice effort, we need to take a more *outcome oriented* approach to assessment. The term *effort* refers to 'a vigorous attempt', which is relative and dependent on the ‘fitness’ of individual learners; e.g. learner can jump 10 times in 2 minutes before reaching exhaustion thus, that number of jumps and length of time is utilised to deliver a practice regime that consists of **High Effort**. The force of an output also presents as a significant variable dynamically related to product and fitness. For example, a user who can jump ‘high’ will find moderate jump repetitions less challenging than ‘high’ jump repetitions. Thus, to facilitate appropriate effort, the parameters that require assessment move beyond the process (skill criteria) to include the product of performance i.e. fitness (how long they can go before fatigue) and force (how high they can jump on average). Results can be utilised to inform the decision making process around what constitutes appropriate ‘practice effort’ for the individual learners.

Finally, **motivation** (Ericsson, 1993) also presents as a necessary principle related to the learner. It is one of the most cited principles for optimal teaching and learning. However, an assessment of the learner’s motivation, in terms of motor acquisition, is less frequently discussed. What we do know is that a lack of motivation can be tackled through adapted instructional and/or feedback delivery. An assessment of learner motivation is quite straightforward. It can often be observed or attained through a direct question that is met with either verbal assent or dissent. Despite the fact that a learner assessment was rarely discussed across the literature, a dynamic set of parameters unfolds almost organically. Further, these parameters are supported by analysing previously outlined principles relating to practice, feedback and instruction. That is, information ascertained about the learner through an assessment of the below parameters directly informs each and every previously outlined principle/condition. This novel learner assessment is outlined below (fig. 3.5)

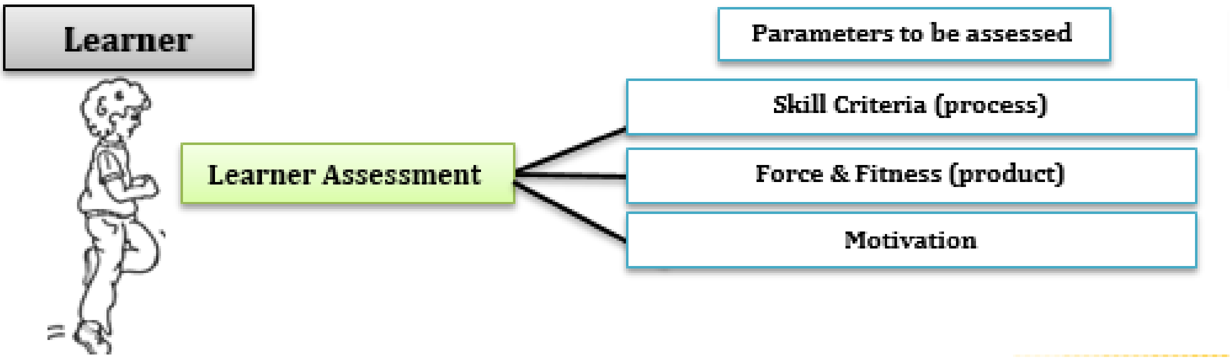


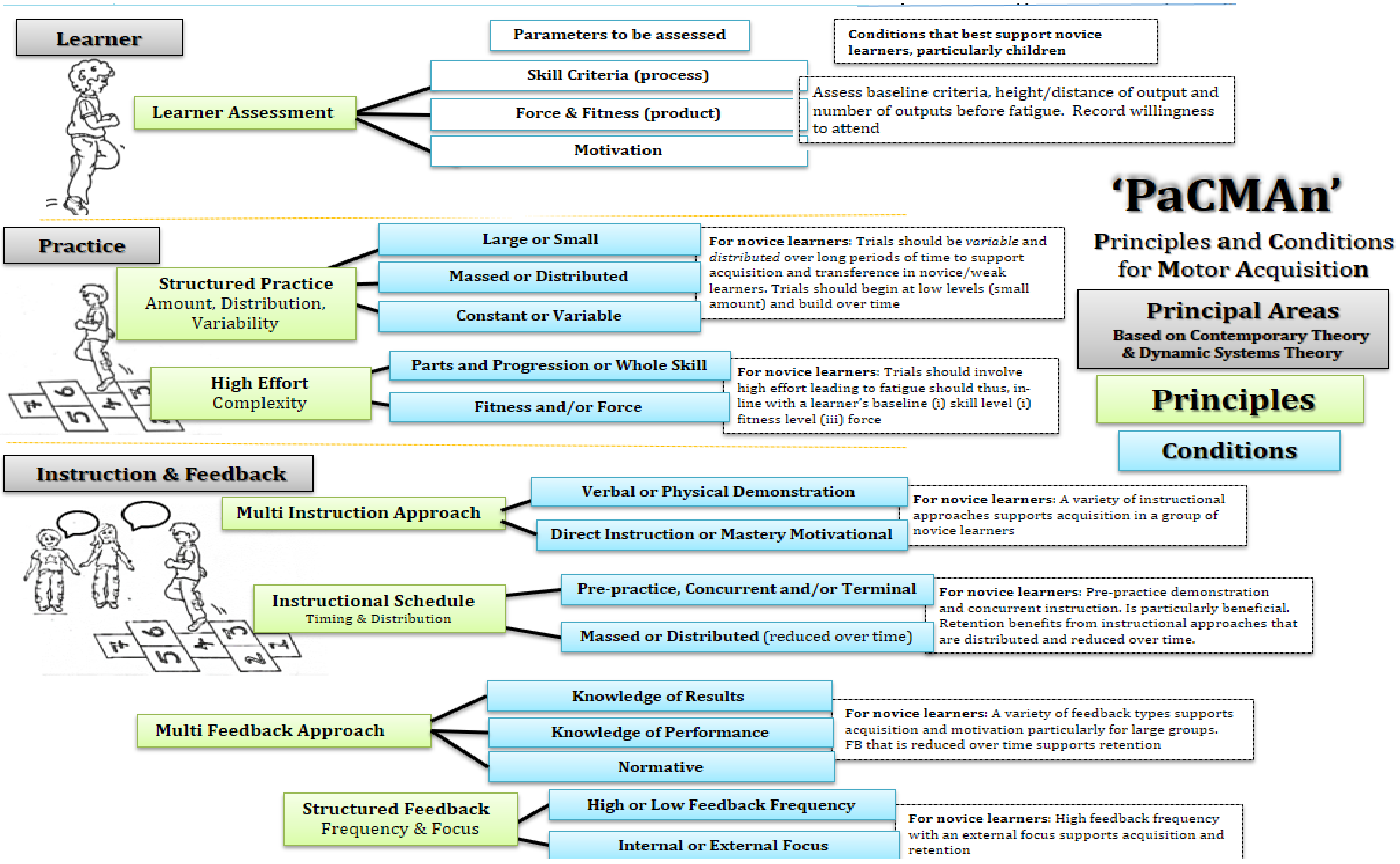
FIGURE 3.4 VARIABLES OF LEARNER ASSESSMENT

3.3 PACMAN: PRINCIPLES AND CONDITIONS OF MOTOR ACQUISITION

Having analysed each principle area in a relatively isolated fashion, it is now time to marry the findings and present an overall outline of principles and conditions for motor acquisition and thus, a **framework** to deliver effective motor acquisition. The framework is entitled **PaCMAn**: **P**rinciples **a**nd **C**onditions of **M**otor **A**cquisition**.** It is illustrated below in table 3.5.

The framework is not only theoretical but practical as it includes parameters for a learner assessment. Essentially, the results of this learner assessment speak to the choice of conditions required to best support individual learner needs. An example of the framework's practicality is illustrated in table 3.6 (p.60). In this example, the rationale behind the choice of conditions is also provided and the provision of each principle can be accounted for; meaning that locomotor acquisition for the sample user is likely to take place at a rapid rate.

TABLE 3.5 PACMAN: PRINCIPLES AND CONDITIONS FOR MOTOR ACQUISITION



‘PaCMAn’

Principles and Conditions for Motor Acquisition

Principal Areas
Based on Contemporary Theory & Dynamic Systems Theory

Principles

Conditions

Learner

Learner Assessment

Parameters to be assessed
- Skill Criteria (process)
- Force & Fitness (product)
- Motivation

Conditions that best support novice learners, particularly children

Assess baseline criteria, height/distance of output and number of outputs before fatigue. Record willingness to attend

Practice

Structured Practice
Amount, Distribution, Variability
- Large or Small
- Massed or Distributed
- Constant or Variable

For novice learners: Trials should be *variable* and *distributed* over long periods of time to support acquisition and transference in novice/weak learners. Trials should begin at low levels (small amount) and build over time

High Effort
Complexity
- Parts and Progression or Whole Skill
- Fitness and/or Force

For novice learners: Trials should involve high effort leading to fatigue should thus, in-line with a learner's baseline (i) skill level (i) fitness level (iii) force

Instruction & Feedback

Multi Instruction Approach
- Verbal or Physical Demonstration
- Direct Instruction or Mastery Motivational

For novice learners: A variety of instructional approaches supports acquisition in a group of novice learners

Instructional Schedule
Timing & Distribution
- Pre-practice, Concurrent and/or Terminal
- Massed or Distributed (reduced over time)

For novice learners: Pre-practice demonstration and concurrent instruction. Is particularly beneficial. Retention benefits from instructional approaches that are distributed and reduced over time.

Multi Feedback Approach
- Knowledge of Results
- Knowledge of Performance
- Normative

For novice learners: A variety of feedback types supports acquisition and motivation particularly for large groups. FB that is reduced over time supports retention

Structured Feedback
Frequency & Focus
- High or Low Feedback Frequency
- Internal or External Focus

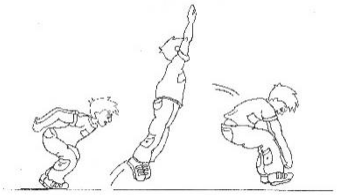
For novice learners: High feedback frequency with an external focus supports acquisition and retention

TABLE 3.6 PACMAN FRAMEWORK IN USE

EXAMPLE

Child's Name: David

Age: 6 (novice learner)



Skill: Jump

	Principle	*Paramters*				
Learner	Assessment	*Skill Criteria*		*Strength* Can jump to a moderate height consistently until fatigue sets in, then struggles to lift two feet off the ground	*Fitness* Fatigued after 27 jumps denoted by third consecutive failed attempt to reach net *Time was 52 seconds*	*Motivation* Gave verbal assent to particpate
		Bend both knees and extend arms behind body	×			
		Bring arms forward and upwards to full extension	×			
		Land with both feet together	✓			
		Arms are brought downwards on landing	×			

*Criteria performed ✓
*Criteria not performed ×

		CONDITIONS		
Practice	Structured	Large or Small Number of Trials, Massed or Distributed **- 2 trials a day, daily, over an 8-week period** *Why?* Novice learners benefit from a small number of trials that increase over time. Trials should be distributed over a long period of time to facilitate retention	Constant or Variable **-Practice Jump – Monday, Tuesday, Wednesday** **-Second skill – Thursday & Friday** *Why?* Novice learners who are weak across all skills benefit from variable practice. On a macro level this variability can refer to practice of multiple skills. At a micro level it refers to working on a variety of skill parts	
	High Effort	Parts of skill or whole skill **-Absent criteria worked on as part of whole skill performance** *Why?* Effort should reflect user capability. If all criteria is absent, focus on skill in parts otherwise focus on absent criteria in whole skill performance	Fitness **-Practice trials should last 60 seconds to elicit 30 jumps** *Why?* Practice length and number of outputs should be in line with results of baseline fitness assessment	*Force* **-Learner should perform jumps of moderate height and maintain moderate height throughout** *Why?* Height of output should not exceed user capability
Instruction	Scheduled	*Pre-practice, Concurrent or Terminal* -**Provide instruction before, during and after practice** *Why?* Novice learners benefit from pre-practice demonstration with concurrent direct instruction	*Massed or Variable* **Some trials omit prepractice demonstration, whilst others omit concurrent instruction** *Why?* Novice learners benefit from variable instruction and instructional approaches. Reduced instruction over time supports retention	
	Multi Type	Direct Instruction **Provide verbal/physical demonstration at prepractice stage, with further direct instruction during/after trials** *Why?* A variety of instructional approaches supports acquisition in groups of novice learners	Mastery Motivational **Allow learner to choose the skill they want to practice every now and then (once a week)** *Why?* Gives the learner ownership over practice and increases motivational levels	

Feedback	Structured	Frequency **High Feedback frequency particularly during gameplay** *Why?* Novice learners benefit from continuous information about how they are doing. Reducing frequency over time supports retention	Focus **Feedback should refer to the effect of the movement e.g. 'bring the ball higher', rather than 'stretch your arms up'** *Why?* referencing body parts causes a division of attention and stunts acquisition	
	Multi Type	Knowledge of Performance **Let learner know how their jumps were performed, how many times they jumped and how fast they were performed** *Why?* KOP facilitates the learner in making appropriate corrections and achieve further success	Knowledge of Results **Let user know if jump had correct criteria and if their target of 30 jumps in 60 seconds was achieved** *Why?* KOR supports continued or improved effort in future trials	Normative **Let learner know how they are doing relative to their peers. Provide false positive if necessary** *Why?* Motivation and confidence is increased with positive normative feedback. Child needs to feel at least as good as their peers

3.4 SUMMARY

This chapter focused on the design of a theoretical and practical framework that could be used to underpin locomotor training programs and support effective acquisition. The construction of this framework began by taking an inductive list of principles and conditions, ascertained through a systematic analysis of the literature on gross motor training/acquisition (in section 2.4), and examining these principles and conditions in a deductive process. This deductive process began by focusing on each *principle area* in isolation; beginning with practice, then instruction, followed by feedback, at which point the parameters for a learner assessment were identified. The results of this assessment are used to inform the decision making process around which combination of conditions best support individual learner needs.

In all, the analysis was conducted with clear goals; (i) to bring a uniformity of language (ii) to decrease the number of rules (principles) and factors (conditions) and (iii) and to support the decisions making process; resulting in a framework that is not merely theoretical but also practical. The end result of this analysis is: PaCMAn, Principles and Conditions for Motor Acquisition. The framework is illustrated in table 3.5 and an example of it 'in practice' followed in table 3.6. The next step is to examine its practical use further; as a *design* framework. Essentially, the next chapter explores the use of PaCMAn to underpin the development of video games intended to support locomotor acquisition through extended gameplay. Accordingly, chapter 4 is concerned with facilitating PaCMAn in a gaming environment and ensuring that all aspects of the framework can be met in some capacity, during the gaming experience.

4 DEVELOPMENT

4.1 INTRODUCTION

This chapter is focused on the development of video games for locomotor acquisition. The intention is to underpin these games with the theoretical framework, PaCMAn, and best support user gains in locomotor acquisition. First, the goal is to identify Principles and conditions that can be delivered by the computer/game which is initially tackled via an analysis of exergames already on the market against the PaCMAn framework. Video games put forward for analysis are noted to elicit locomotor outputs from the user (previously outlined in state of the art, table 2.3). Although these games were not purposely designed to support locomotor acquisition, they provide an insight into what parts of the PaCMAn framework can be supported by the computer (or game) and what parts of the framework require some other means of (human) delivery. Game design features that potentially correlate with motor learning principles, are also analysed. Conversely, several principles and conditions are identified as unable to be supported by a computer/game owing to technical limitations. However, these short comings are potentially negotiated via an adaptive process between the game and teacher. This process involves the teacher adjusting parameters of the gameplay via adaption of several 'design features' e.g. timer, score board, target etc. in order to facilitate motor learning principles that the game cannot.

Consequently, a suitable authoring tool is identified, one that facilitates the development of 'adaptable' games for locomotor acquisition. These games are intended to support instant adaption of design features by a 'human adaptive component', the teacher. The development and rationale for these features is also outlined. Finally, a hypothetical outline of the adaptive process required between teacher and game to deliver the principled framework is presented.

4.2 ANALYSIS OF EXERGAMES ON THE MARKET AGAINST THE PACMAN FRAMEWORK

In section 2.3, the exergames *Your Shape* (Microsoft, 2012a), *Kinect Sports* (Microsoft, 2012), *EA Active Sports* (Nintendo, 2009) and *Wii Fit* (Nintendo, 2011) were identified as eliciting locomotor outputs from the user. For example, sequential hops are called upon for 'jump rope' (Your Shape), skipping is called upon for 'goal kicks' (EA Active Sports), jumping is required when playing '400m hurdles' (Kinect Sports) and sliding is called for as part of 'goal keeper' (EA Active Sports) (previously outlined, table 2.3). The 'pre-practice' graphic model in each game also references locomotor criteria outlined in the TGMD (Ulrich, 2000). Thus, these video games appear promising in terms of potentially supporting locomotor training and acquisition. However, none of these games were designed for motor training purposes and conversely, they do not attempt to measure performance criteria. Further, as table 2.2 demonstrates, sensor accuracy is so limited that the effective measurement of full locomotor criteria with affordable 3D sensors is currently a 'technical' impossibility.

Additionally, users typically cheat locomotor outputs to limit energy expenditure and upon doing so, can still achieve game success. This is because the game is simply unaware that an intended jump has been cheated as it is unable to accurately assess the 'process' of performance (skill criteria). On the flip side, these commercial games demonstrate the capacity to assess the *product* of the outputs (skill strength/fitness). For example, 'Jump Rope' was created to burn calories and provide workouts based on user fitness level (Microsoft, 2012a). It measures the user's fitness level by tracking the rate of their jumps; essentially, how accurately a user can perform a rhythmical sequence of locomotor outputs. The game then uses this as an input to adjust the rate (speed) of the sequence, slowing down to cater for relatively unfit users and speeding up for those deemed as precise. Conversely, the 400m hurdles (Kinect Sports), assess the height of the user's jump. This means, that hurdles only stay upright if the user jumps to a specific height. However, adjusting the height of jump required from the user is not an option; moreover, the height of a jump is easily cheated by moving closer to the sensor. The same applies to EA Sports Active and Wii Fit, i.e. the parameters of gameplay do not change to meet the user's abilities and the assessment of these abilities can be skewed depending on the position of the user relative to the sensor.

In all, commercial video games do not attempt to assess the user's locomotor skill criteria (performance process), nor can they accurately do so owing to technical limitations. Whilst some games attempt to measure aspects of the user's strength and fitness level (performance product), this assessment is often skewed depending on the position of the user and results are rarely used to change parameters of gameplay. However, the potential for a game to do just that, is evident, particularly in *Your Shape* – 'jump rope' (discussed later in further detail, figure 4.1 p.65). Ultimately, games on the market do not and cannot accurately assess user performance. Furthermore, conditions relating to the delivery of PaCMAn are determined by the results of a learner assessment. Ergo, video games on the market cannot provide appropriate practice, feedback or instruction since this baseline assessment is not and, for the most part, cannot be performed. Table 4.1, below, highlights this fact by analysing commercial video games that elicit locomotor outputs from the user against principles and conditions relating to a learner assessment.

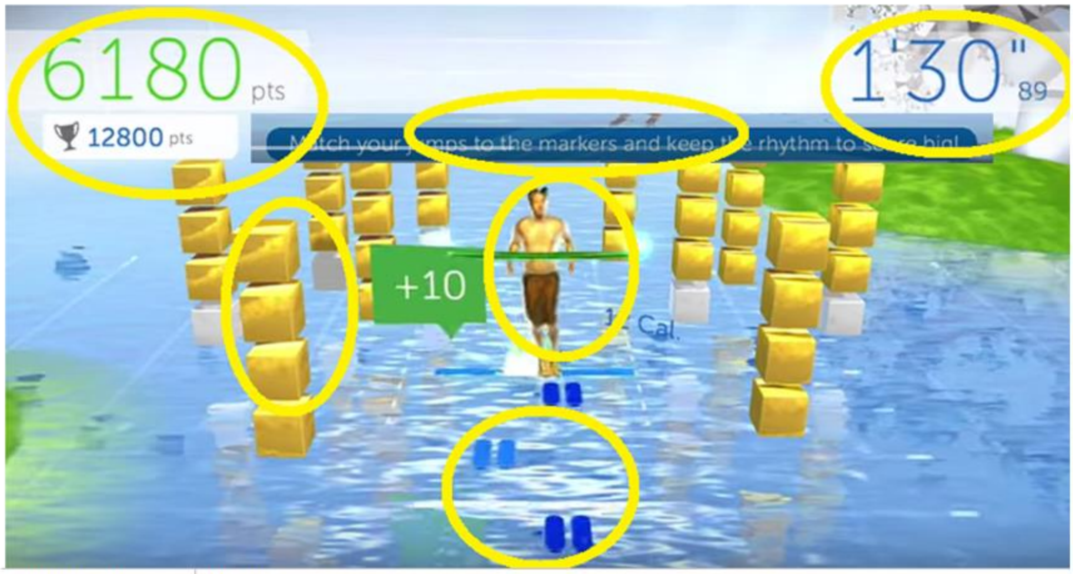
TABLE 4.1 ABSENT PACMAN IN GAMES ON THE MARKET

Learner Assessment	Your Shape **Jump Rope**	Kinect Sports **400m Hurdles**	EA Sports Active **Kicks** Goal Keeper	Wii Fit **Ski Jump**
Skill Criteria (process)	✗	✗	✗	✗
Strength & Fitness (product)	✓	✓	✓	✗
Accurate Assessment of User Output During Gameplay (preventing cheated outputs)	✗	✗	✗	✗

✓ = potentially *accounted for to some extent*
✗ *= not accounted for in design*

A further analysis of these games against a full PaCMAn framework identifies an array of principles and conditions currently unsupported in a video game environment. Equally, it highlights principles and conditions that *are* potentially supported. For example, figure 4.1 outlines design features in the game 'Jump Rope' that correlate with PaCMAn. These represent a list of hypothetically adaptable features, capable of shifting conditions relating to practice, feedback and instruction and personalising gameplay towards individual user needs. The biggest issue revealed by the analysis of popular exergames on the market is the lack of baseline assessment, which stems from both design and technical limitations. This means that several principles and conditions cannot be supported. However, if an assessment could be supported, the potential is there to utilise results as inputs and personalise game play/adapt design features to suit individual user capabilities and needs. Theoretically, this assessment could be performed by the teacher, a relative expert in locomotor assessment. The teacher could then adapt a set of design features and shift the parameters of gameplay based on the results of these baseline assessments. The question is, what design features are capable of facilitating PaCMAn and supporting locomotor acquisition and how does a teacher adapt these features in line with individual user needs.

Figure 4.1 illustrates a series of design features identified in Jump Rope (Microsoft, 2012a) and highlights the principles/conditions that these features potentially correlate with. Following this, table 4.2 presents a more thorough checklist of findings from an analysis on commercial exergames (that elicit locomotor outputs from the user). This checklist highlights principles and conditions that are currently supported/unsupported in a gaming environment.



	CONDITION	NOTES
ASSESSMENT OF LEARNER	 **FITNESS**	✓ - Footprints appear in rolling fashion to instigate rate, rhythm and orientation of jumps - Fitness and energy assessed by ability to maintain rate and rhythm - Fitness level informs the structure of the task - Structure changes as the user fitness improves
PRACTICE	 **PRACTICE AMOUNT**	✓ - Timer dictates length of practice - Footprints indicate amount of jumps
	VARIABILITY	✓ - Footprints change orientation of jumps (straight line or left to right) - Footprints are variable changing speed of jumps - Footprints dictate jump criteria - 2 feet or one foot
	COMPLEXITY	✓ - High effort maintained through continuous fitness assessment from initial fitness test
Feedback	 **FEEDBACK TYPE**	✓ - Knowledge of results via rolling score - Successful outputs result in gold blocks
	FREQUENCY 	✓ - Gold block appears after every 10 successful jumps - Represents delayed feedback frequency - Points system only viewed when player chooses
INSTRUCTION		✓ - Figure and footprints model skill - Words articulate goal and reward

FIGURE 4.1 DESIGN FEATURES OF JUMP ROPE THAT CORRELATE WITH PACMAN

TABLE 4.2 PACMAN IN EXERGAMES ALREADY ON THE MARKET

	Learner			**Practice**			**Instruction**			**Feedback**			
	Learner Assessment *Process (skill criteria)*	**Learner Assessment** *Product (Fitness and Strength)*	**Motivation** Verbal or Observed Assent	**Structured Practice** *Amount and Variability*	**Practice Effort** *Whole or parts skill*	**Practice Effort** *Fitness and strength*	**Instructional Type** *Direct Instruction*	**Instructional Type** *Mastery Motivational*	**Structured Instruction** *Timing & Schedule*	**Multi Feedback Type** *Knowledge of Performance*	**Multi Feedback Type** *Knowledge of Results*	**Multi Feedback Type** *Normative*	**Structured Feedback** *High or Low FF*
Your Shape Jump Rope	*n/a*	*✓	✗	*✓	✗	✓	✓	✗	*✓	*✓	*✓	✗	✗
Kinect Sports Volleyball 400m Hurdles	*n/a*	*✓	✗	*✓	✗	✗	✓	✗	*✓	*✓	*✓	✗	✗
EA Sports Active Kicks Goal Keeper	*n/a*	*✓	✗	✗	✗	✓	✓	✗	*✓	*✓	*✓	✗	✗
Wii Fit Ski Jump	*n/a*	*✓	✗	✗	✗	✗	✓	✗	*✓	*✓	*✓	✗	✗

n/a *= not applicable, technical limitations*
✓ *= accounted for in design (to some extent)*
*✓ *= could potentially be accounted for*
✗ *= not accounted for in design*

Design features outlined in Your Shape: Jump Rope (Microsoft, 2012a) could be utilised for the development of purpose built video games for locomotor acquisition. That is, these features potentially correlate with PaCMAn and have the capacity to shift gaming parameters and meet individual user needs. Essentially, we now hold two hypothetical points of view. First, without current technical limitations a video game could perform a full baseline learner assessment and use the results to change parameters of gameplay to suit user needs. Second, these user needs could be supported with the adaption of several design features affecting conditions relating to practice, instruction and feedback; but can assessment or adaption be facilitated during gameplay without a 'technical' breakthrough?

Previously, in section 2.2, Levac et al., (2015) informed us that video games are successfully used in motor rehabilitation when clinicians carefully choose and adapt exergames to suit the needs of their patients. This could be described as an *adaptive process* between game and clinician. This adaption involves a manipulation of hardware, e.g. power off to end the game when patient is fatigued and re-positioning the 3D sensor to alter required outputs. Alternatively, these same parameters could be adjusted if games came with adaptable features such as game timer or score board etc. That is, the adaption of a game timer could facilitate a personalised length of play (duration) to meet user fitness levels.

This type of adaptive process could be extended to several design features that correlate specifically with motor learning principles and conditions. Thus, allowing for the delivery of PaCMAn through video gameplay in the classroom setting. In this scenario, the teacher could negotiate 3D sensor limitations by delivering parts of the framework that the game cannot. This could be done by adapting game design features to suit the needs of individual learners. Hypothetically, the teacher assesses the user's baseline performance level and, with the results ascertained, adapts game features to suit individual needs. The difficulty with this potential model is that the features of commercial exergames are 'locked in' and 'virtually' impossible to adapt. As such, we need adaptable video games containing design features that correlate with motor learning principles and conditions. Teachers also have to feel comfortable and capable during this adaption process in order to effectively deploy video games for locomotor acquisition in the classroom setting. As such, the first step in the development process is to identify a suitable authoring tool that can appeal to teachers and facilitate instant adaption of its features. A tool, familiar to teachers is outlined in the following section (4.3).

4.3 DEVELOPMENT OF VIDEO GAMES FOR LOCOMOTOR ACQUISITION: STEP 1

Identification of an Appropriate Authoring Tool

This study aims to develop a series of adaptable video games to investigate if an adaptive process between game and teacher can be effectively deployed in the classroom and support improved locomotor skills in users. Whilst future, more sophisticated, versions of these games should provide slick controls that facilitate the adaptions PaCMAn requires, such refined controls are not necessarily required for the purpose of this study. That is, the main gaming objective in this thesis is to (i) elicit locomotor outputs from the user and (ii) allow for the instant adaption of design features/gaming parameters with relative ease. In addition, it is important for teachers to feel comfortable and capable when performing this adaptive process.

With that in mind, 'Scratch', the graphical drag and drop event-driven programming framework developed by Massachusetts Institute of Technology, stands out as a potential platform. It is used in schools worldwide to develop numeracy skills and introduce young children to coding. For example, in Ireland, continuous professional development (CPD) on the use of Scratch in the classroom is offered to all teachers across the country; it is also highlighted as an important teaching tool in the *national digital strategy plan* (Department of Education & Skills, 2015). Consequently, many teachers are familiar with the tool and even have experience using it in the classroom setting.

Scratch is a visual, block-based, computer programming language editor that uses puzzle-like pieces instead of complex code normally required in game design (figure 4.2).

C# Code for command "Go".

```
public class Go{
        public static void main(String args[]){
                System.out.println("Go!");
        }
}
```

Scratch 'puzzle piece' for command "Go".

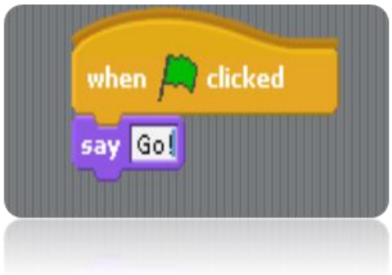


FIGURE 4.2 C# LANGUAGE VERSUS SCRATCH PUZZLE PIECES

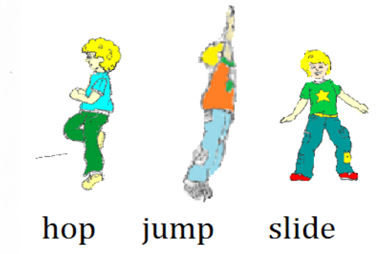
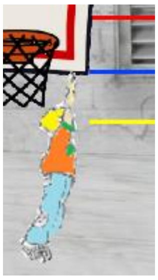
The block-based editor allows any aspect of game design to be (re)configured 'on the go'. Furthermore, a Kinect interface can be linked with Scratch to enable full body control. This is made possible through the use of Stephen Howell's (2012) *Kinect2Scratch*, a free bridging library that removes the need for complex C# and C++ programming skills. An OpenNI2Scratch program enables users to send joint positions to Scratch via Kinect. Once again, puzzle like variables can be manipulated, this time to determine which set of joint movements control gameplay. Ergo, any locomotor skill can become a means of game control. Furthermore, any game design feature and parameter can be altered with ease, by a teacher, to differentiate for individual learner needs, making the process of video game adaption viable, and potentially familiar, in the classroom setting.

4.4 DEVELOPMENT OF VIDEO GAMES FOR LOCOMOTOR ACQUISITION: STEP 2

Development of Game Design Features

Thus far, an underpinning design framework has been presented and an analysis of video games currently on the market has revealed parts of this framework that are currently not supported owing to current technical limitations. An adaptive process between game and teacher is put forward as a means of overcoming these limitations. This involves the teacher implementing an initial baseline learner assessment and adapting game design features (that correlate with principles and conditions of motor training/acquisition) to suit learner needs. Scratch has been presented as a potentially suitable authoring platform that facilitates instant adaption of gaming features by teachers who are typically familiar with the tool and its layout. The next step calls for the development of adaptable design features, ensuring that they correlate with PaCMAn. These features, which were informed by an analysis of popular games already on the market (section 4.3), are illustrated below (table 4.4).

TABLE 4.3 DEVELOPMENT OF GAME DESIGN FEATURES, ADAPTED TO FACILITATE PACMAN

CHARACTER  **INSTRUCTIONAL TYPE:** DEMONSTRATION	Games for locomotor acquisition should feature a character that provides a demonstration of the locomotor skill and criteria 
TIME  **PRACTICE AMOUNT & FEEDBACK** **(KNOWLEDGE OF PERFORMANCE/KNOWLEDGE OF RESULTS)**	A countdown clock represents an adaptable feature used to dictate a suitable amount of practice (or gameplay) in line with the user's *fitness* level. Play should be sustained without leading to exhaustion. The timer can also be utilised to assist with assessment and help denote the time of fatigue/exhaustion, marking the baseline fitness level of the user. It can also be used as a reference point for instruction and feedback e.g. "you're going faster than your first attempt".
SCORE  **MULTI TYPE FEEDBACK:** KOR/NORMATIVE FB	A scoreboard provides *knowledge of results*, and motivates future efforts. Scoring systems are also utilised to create false positives. For example, a strong child may achieve one point for a goal, whilst a weaker child may score 2 points. It facilitates false positives and also acts as a point of reference for instruction and feedback e.g. "I want you to achieve 10 points", "you have 5 more points than your last turn".
VISUAL FEATURES  **STRUCTURED FEEDBACK:** MOVEMENT EFFECT	Visual features such as basketballs and nets can be referenced to facilitate *movement effect* and prevent distraction e.g. "bring your ball high up to the net" replaces, "lift your arms". 
HEIGHT LINES  **LEARNER ASSESSMENT** FORCE	Coloured 'height lines' support the assessment process by providing a visible measure of height or distance. This variable is difficult to measure in real life settings but easily supported in a video game environment. For the character to reach the red line, it requires a high jump, the yellow line indicates a low jump etc.. In order for the height lines to be effective, the user must be placed at an appropriate distance from the sensor and remain at that distance throughout.

MULTIPLAYER  **MULTI FEEDBACK TYPE:** NORMATIVE FEEDBACK	Multi-player options allow for normative feedback between peers as well as peer modelling. It provides an opportunity to learn from successful others. It also affords an assessment of two users simultaneously.
BASELINE  **SET UP**	A red baseline provides a point of reference to ensure that users stand at the appropriate distance from the sensor. When the game character's feet touch the red line, the user is accurately aligned and should not stray from this mark.

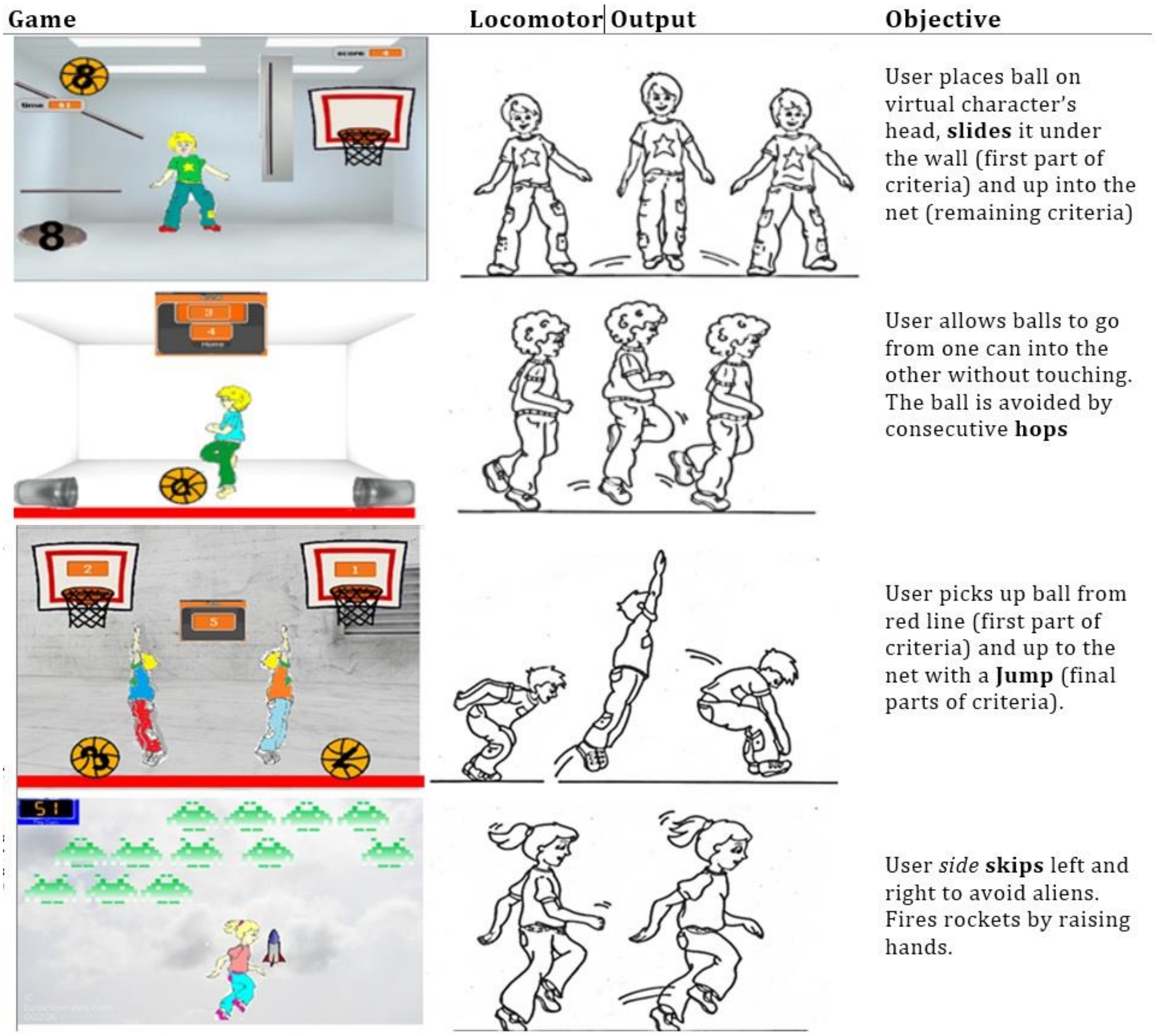
The design features illustrated in table 4.4 were developed in Scratch and, in-turn, link with Kinect2Scratch. In total, four purpose built adaptable games were developed to support the potential acquisition of four locomotor skills; hop, skip, jump and slide. In order for these games to work effectively, they require an adaptive process between teacher and game. This is somewhat supported by offering teachers a tool they are typically familiar with (Scratch). However, we know that teachers generally lack knowledge and understanding around how to deploy video games for motor learning purposes (Vernadakis et al., 2015). Essentially, teachers need to know, in detail, what exactly is expected of them. What features to adapt, when to adapt them and so on. They require a concise *guide* to adaption and deployment. As such, a guide to adaption and deployment is systematically evaluated in chapter 5.

Before that, section 4.5 outlines the four purpose built adaptable video games for locomotor acquisition and provides an initial (hypothetical) outline of the adaptive process required between teacher/game. The games include, *Hop Ball, Jump Ball* and *Slide Ball* with an existing game, Alien Attack (Howell, 2012) that has been altered to foster skipping. Thus, each game calls for a specific locomotor output and specific locomotor criteria informed by TGMD-2 (Ulrich, 2000). The game series is entitled 'Locogames'.

4.5 DEVELOPMENT OF VIDEO GAMES FOR LOCOMOTOR ACQUISITION: STEP 3

Outline of the Adaptive Process (hypothetical)

A series of adaptable video games to support locomotor acquisition were built for the purpose of this study. These games facilitate an adaptive process to allow for the provision of PaCMAn in a video game environment and therefore, potentially effective acquisition of locomotor skills. There are four games purposely designed to target four locomotor skills; hop, skip, jump and slide. All games aim to elicit locomotor criteria identical to that laid out in the TGMD-2 (Ulrich, 2000). However, Skip Attack (an adapted version of Alien Attack by Stephen Howell) is unable to facilitate forward skipping owing to logistical/space considerations. Interestingly, Sidaway et al., (2012) state that practicing a motor pattern similar to a desired skill may lead to effective transfer of that skill as a result of 'generalization'. Thus, Skip Attack aims to foster a *side skipping* pattern that is later transformed into effective forward skipping, because of similarities between both output patterns. Individual games and their corresponding targeted outputs are outlined below, fig.4.3.



User places ball on virtual character's head, **slides** it under the wall (first part of criteria) and up into the net (remaining criteria)

User allows balls to go from one can into the other without touching. The ball is avoided by consecutive **hops**

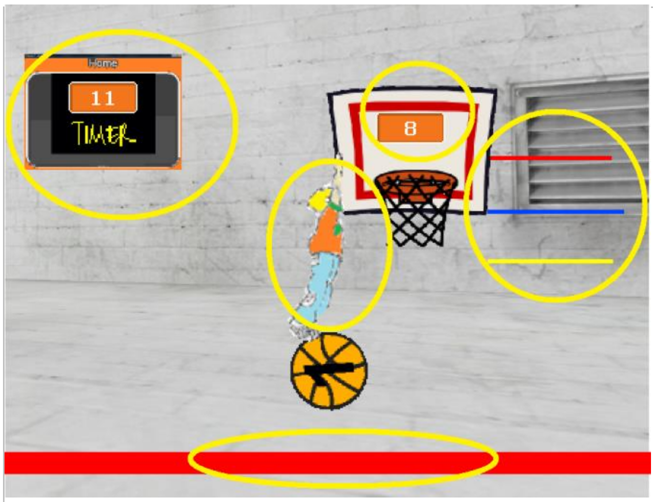
User picks up ball from red line (first part of criteria) and up to the net with a **Jump** (final parts of criteria).

User *side* **skips** left and right to avoid aliens. Fires rockets by raising hands.

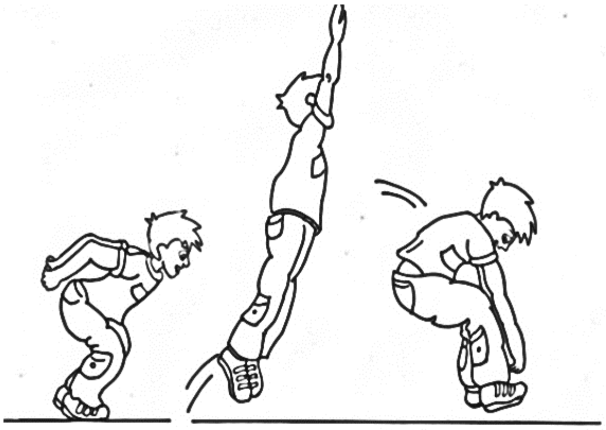
FIGURE 4.3 LOCOGAMES: SLIDE BALL, HOP BALL, JUMP BALL AND SKIP ATTACK

Locogames were developed using Scratch and Kinect2Scratch (Howell, 2011). This allows for the instant adaption of game design features and thus, an adaptive process between teacher and game. However, this adaption process requires further attention. Essentially, the teacher needs to know what is expected of them. First, a tentative and hypothetical outline of the adaptive process is described in table 4.5 (following page) using the example of *Jump Ball.* However, it is important to note that this process (as well as an overall guide to deployment) requires a more rigorous evaluation and concise articulation. This will take place in chapter 5.

TABLE 4.4 JUMP BALL, INITIAL OUTLINE OF THE ADAPTIVE PROCESS BETWEEN GAME AND TEACHER

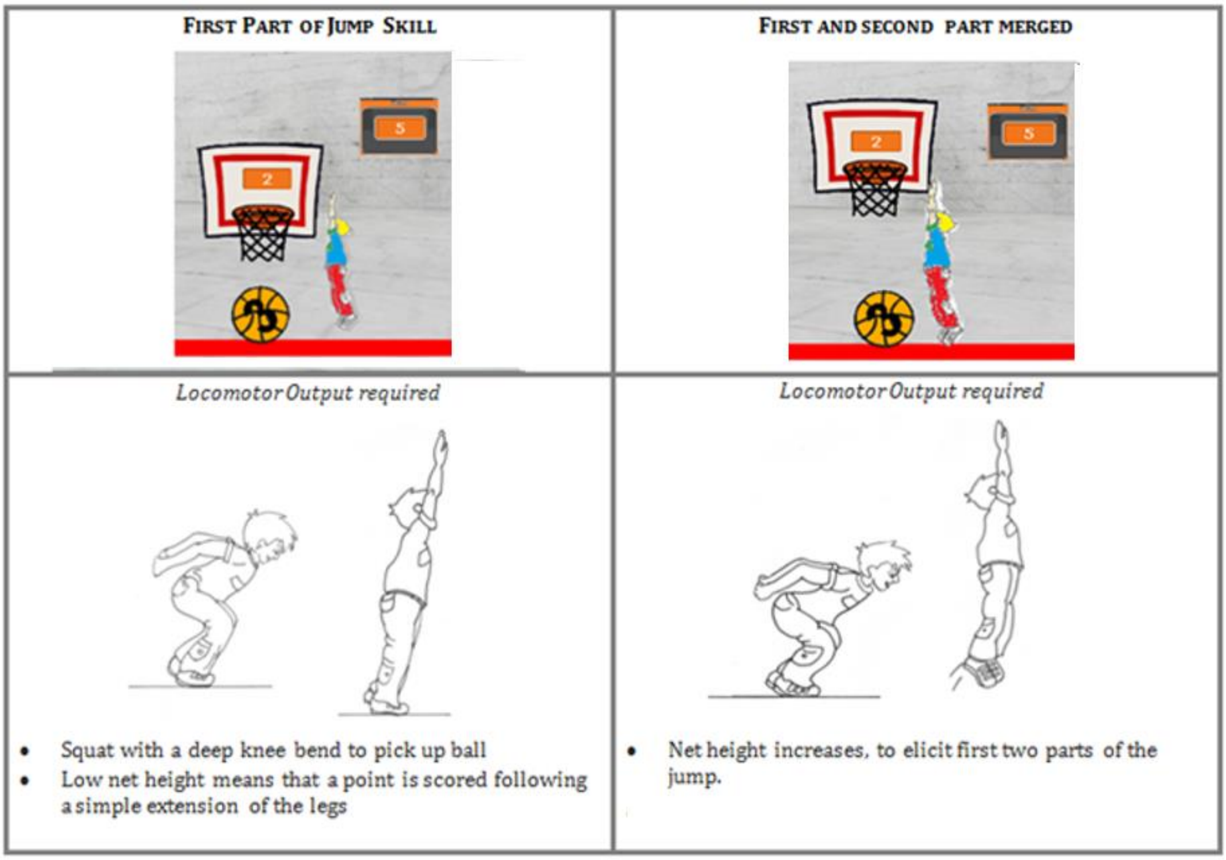


Output required



Principle	Condition	How
Learner Assessment	*Process (Skill Criteria)*	Child plays a 'prelimary game', **teacher** assesses skill criteria during gameplay, identifies criteria that require focus
	Outcome (fitness/force)	**Teacher** notes point of fatigue i.e. when child is no longer able to reach net and height of average jump decreases Time tracked using **game** timer **Teacher** notes averge height/force of output by paying attention to the **game** height lines reached by online character – e.g. yellow line denotes a low jump etc.
	Motivation (Verbal/Observed Assent)	**Teacher** asks for verbal assent to participate in gameplay **Teacher** observes user effort as typical or non-typical to that child
Practice Effort	*Fitness & Force*	**Game** features (i.e net & timer) adapted by teacher to ensure effort is in line with child's performance level Height of net determined by how high the user can jump, length of gameplay determined by the user's point of fatigue
Structured Practice	*Parts & Progression*	**Teacher** adjusts the net to a low net height (yellow line) in order to focus on 1st part of jump criteria Teacher adjusts net to moderate or high in order to work on criteria within a whole skill performance
	Practice Amount	Practice schedule decided upon and deployed by **teacher**
	Constant or Variable *Large or Small Number of trials*	Variablility dictated by **teacher** who decides what game to play, ergo what skill to work on and how many times the child will play
Instruction Type	*Verbal Demonstration*	**Teacher** informs child of game objectives and of skill criteria
	Physical Demonstration	**Teacher** models jump criteria prior to gameplay (pre-practice)
	Visual Demonstration	Provided for by **game's** on-screen figure models jump
Instruction Type	*Direct Instruction*	**Teacher** provides clear instructions of game objective and skill criteria & references game features to elicit a movement response i.e. get high up to the net
	Mastery Motivational	Child chooses game, but features are adapted without their knowledge to direct them to specific criteria
Feedback Type	*Knowledge of Results* *Knowledge of Performance*	**Game** score represents number of successful jumps performed. **Teacher** provides additional information relating to KOP & KOR
	Normative	**Game** score achieved is compared to peers. False positive facilitated by **teacher** who alters score system so that less able child achieves 3 points per basket, compared to 2 or 1 point given to more able children. **Game** offers multi player option

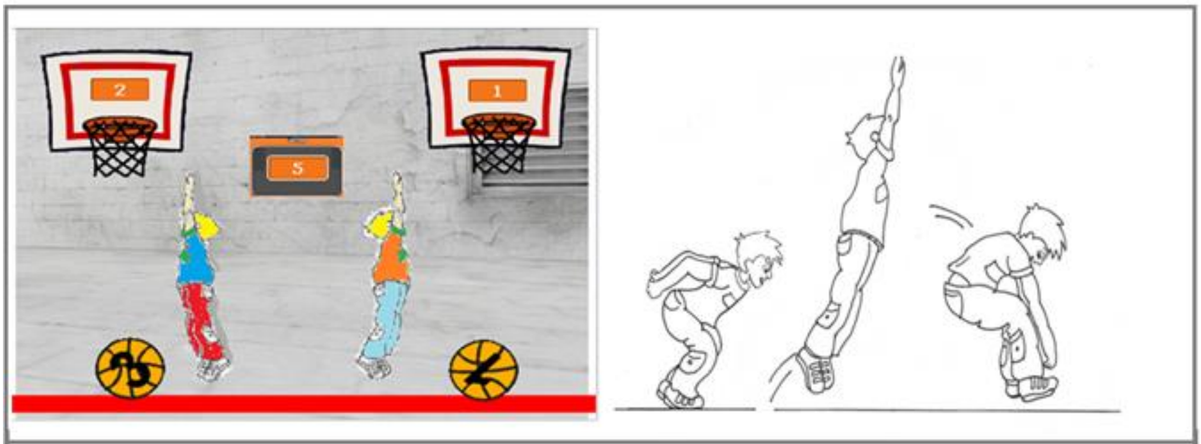
The are several finer details of this adaptive process that warrant attention. For example, Dror (2008) states that video games can readily eliminate additional information and direct the learner towards the most important parts of instruction. This suggests that a user's focus can be drawn towards specific jump criteria and various levels of complexity with basic modification of design features. Consequently, in Jump Ball, the adaption of net height can affect **practice effort**, not only in terms of how high the user jumps, but also the criteria they focus on. Figures 4.4 and 4.5 illustrate how this adaption of net height can focus the user's attention to the first two parts of a jump, whilst a further adaption (higher net) elicits a full (whole skill) jump. This means that conditions relating to user effort, namely *whole skill or parts of skill* can be supported with the click of a button.



- Squat with a deep knee bend to pick up ball
- Low net height means that a point is scored following a simple extension of the legs

- Net height increases, to elicit first two parts of the jump.

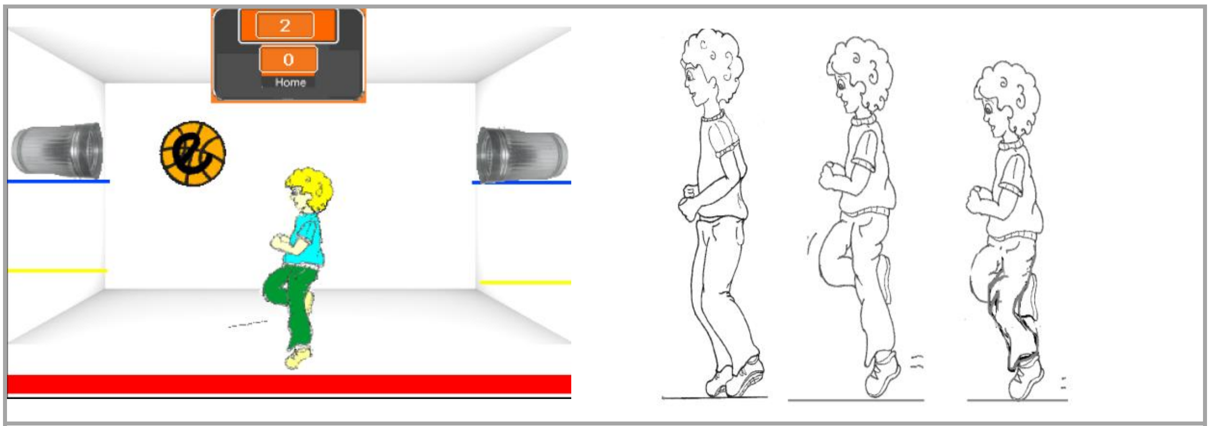
FIGURE 4.4 NET ADJUSTMENT TO ELICIT PARTS OR WHOLE SKILL



- High net elicits full jump, as outlined in the TGMD (Ulrich, 2000)
- High level of force required,meaning user's arms naturally swing downwards after highpoint is reached meeting final part of jump criteria

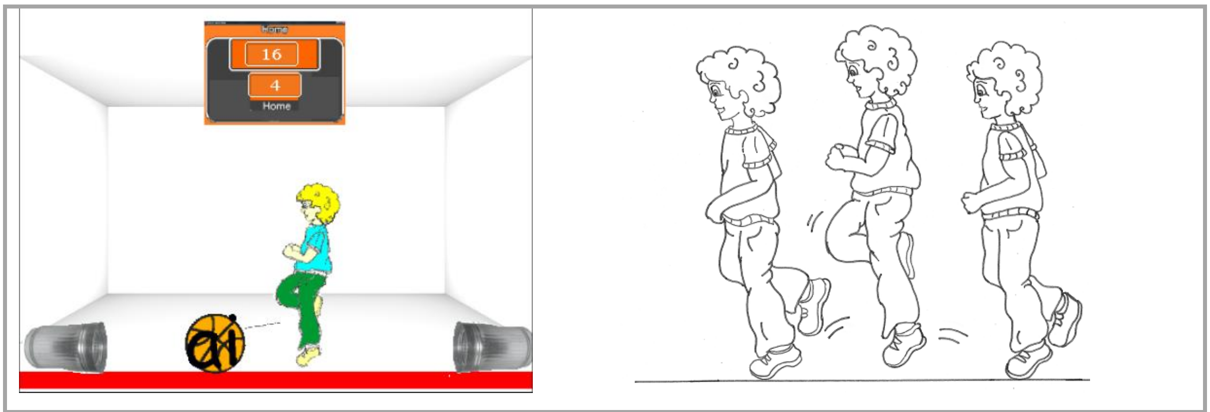
FIGURE 4.5 NET ADJUSTMENT TO ELICIT WHOLE SKILL AND FULL FORCE

The user's attention can be drawn to different parts of a skill or the whole skill, in much the same way across all 'Locogames' but with some slight differences. For example, in Hop Ball, the user's aim is to avoid a ball passing overhead, which elicits the first part of hop criteria (fig, 4.6). The aim of the game can also be adapted so that the user has to avoid a ball passing at ground level. This shifts the desired output towards full hop criteria (fig. 4.7). The rate and speed of the reappearing ball can also be adapted to set a fast, moderate or slow sequence of repeated hops (or jumps, slides, skips etc.). This simple adaption process that directs user attention towards specific skill (hop) criteria is outlined below.



- High targets elicit parts of the hop skill
- User holds 'hop shape' (legs and arms), bends knee to avoid ball allowing it to move from one dustbin to the other, scoring a point
- If user's head touches ball, no points are scored
- Speed and rate of the ball determine the speed and number of knee bends required

FIGURE 4.6 TARGET HEIGHT ADJUSTMENT TO ELICIT PARTS OF A HOP



- Low targets elicit full hop skill
- User performs full hop to avoid ball, allowing it to move from one dustbin to another and score points
- If user's foot touches ball, no points are scored
- Speed and rate of the ball can also be adapted to determine the speed and number of sequential hops required

FIGURE 4.7 TARGET HEIGHT ADJUSTMENT TO ELICIT WHOLE SKILL CRITERIA (HOP)

The previous illustrations relate to micro nuances of game adaption, specifically relating to directing a user's attention towards parts of a skill or a whole skill and thus facilitating appropriate 'practice effort'. A more macro overview of the deployment process can be observed in the video below. This video was captured in the school setting during the research period and focuses on the cohort's participation in 'Jump Ball'.

FIGURE 4.8 VIDEO CAPTURING LOCOGAMES AND THE ADAPTION PROCESS IN ACTION

URL: https://jamiemcgann.com/phd-research/locogames/

Ultimately, PaCMAn is supported in these purpose built video games through an adaptive process between game and teacher. The teacher delivers a baseline learner assessment then utilises results as inputs of gameplay. This involves the adaption of design features which correlate with PaCMAn. Further, the teacher provides additional motor learning principles and conditions, specifically feedback and instruction, typically using the game and its features as a point of reference.

4.6 SUMMARY

This chapter outlined the development of purpose built video games designed to deliver a PaCMAn framework through video gameplay in the classroom. An analysis of exergames already on the market was carried out. These existing games were not purposely designed to support locomotor acquisition but call for locomotor outputs from the user. It was determined that these games did not/could not support PaCMAn in full because they lacked intentional design and were bound by current 3D sensor technical limitations. These findings did not deter the development process, but rather informed it. Studies on the use of exergames for the rehabilitation of basic motor movements, physical fitness and balance etc., prompted the use of what could be described as a 'human adaptive component' (instructor, clinician, teacher etc.) to overcome currently existing technical limitations in order to support PaCMAn that a game/computer cannot.

The role of the teacher was outlined as being threefold; (i) to assess the user's baseline performance level, (ii) to adapt game design features in line with individual user needs and (iii) to deliver additional feedback and instruction that the game cannot. Design features were informed by an analysis of popular exergames which identified a correlation between specific gaming features and specific motor learning principles/conditions. In essence, these design features are potentially adapted to control parameters of gameplay and as such, can be adjusted to suit individual user needs. Given that popular exergames on the market are rarely adaptable, four games were developed 'from Scratch' using the drag and drop based authoring tool (Scratch with Kinect2Scratch) that teachers are largely familiar with. These games were intended to be adaptable and make the deployment process more viable for teachers with an interface that is familiar, and allows for instant adaption at runtime.

A tentative outline of the adaptive process required between teacher and game to facilitate PaCMAn was presented in table 4.5. This was described as 'tentative' because several barriers still exist. First, when it comes to deployment, PaCMAn informs the adaptive process but there is a level of *intuition* expected from the teacher. Relying on intuition means that adaption will be interpreted differently from one teacher to another, resulting in an inconsistent deployment process. Essentially, teachers require a *guide* to outline their role in detail and provide a rubric that facilitates consistent, and more importantly, *effective* deployment.

In relation to 'effectiveness', the success of video games as a training platform for locomotor acquisition in the classroom requires significant attention and evaluation. Empirical evidence is needed to support their worth. Data collected over a period of action research in a school setting has the potential to speak to the effectiveness of video games for locomotor acquisition from two perspectives. First from the point of view of the teacher by tracking and appraising their experiences with deployment (can the teacher do all of the things expected of them?). Second, from the point of view of the learner by quantitatively analysing the effects of gameplay on motor acquisition (does an extended period of gameplay facilitate improved locomotor skills?). This type of data could ultimately speak to the effectiveness of purpose built video games outlined in this study, and also, to an ideal blueprint for future, more sophisticated, versions of video games for locomotor acquisition. Chapter 5 presents the results and findings from a series of evaluations carried out over a period of action research.

5 EVALUATION

5.1 INTRODUCTION

This chapter analyses results from a period of action research conducted in a school setting to address the research question:

How can video games for locomotor acquisition be designed for effective deployment in the classroom?

The research question is divided into **two parts** and initially focused on the *design and deployment of video games for locomotor acquisition in the classroom.* The second part of the research question is concerned with an evaluation into the *effectiveness of these games* in terms of the deployment process (teacher) and user performance (learner). In relation to **design** and **deployment**, the PaCMAn framework (articulated in chapter 3) represents one piece of the puzzle but is largely untested. Therefore, it is important to identify how it is delivered through video gameplay in a classroom setting. Essentially, what parts of PaCMAn are delivered by the game and what parts require the support of a human adaptive component (the teacher)? It is also important to identify specifics relating to the adaption process, essentially what does the teacher have to do in order to meet individual user needs? Answers to these questions can be utilised to create a 'guide' that informs the **deployment** process of video games for locomotor acquisition in the classroom. The second part of the research question is concerned with the **effectiveness** of these games, first from the point of view of the teacher i.e. are they capable of the deployment process; then from the point of view of the learner i.e. does an extended period of gameplay facilitate improved locomotor skills?

5.2 EVALUATION OVERVIEW

Ethical approval was obtained prior to commencing a cycle of action research in the classroom, which included three evaluations, specifically; (i) an analysis of the teacher adaptation and deployment process, (ii) an evaluation into the effectiveness of this deployment process from the teacher's point of view and (iii) an evaluation into the effectiveness of video games for locomotor acquisition from the learner's point of view. More detail relating to these evaluations is presented in section 5.3. Following this, section 5.4 presents the results and findings ascertained over the action research period. The first set of results address the first part of the research question concerning design and deployment. Results here relate to the delivery of a PaCMAn design framework in a video game environment and the overall deployment process required between teacher and game. Qualitative data is analysed and a *Teacher Adaption and Deployment Guide* is articulated.

The second set of results address the second part of the research question, concerned with an evaluation into the effectiveness of video games for locomotor acquisition in the classroom. First, effectiveness is qualitatively evaluated from the point of view of the teacher i.e. are teachers capable of adapting video games to suit individual learner needs. Then, effectiveness is quantitatively evaluated from the point of view of the learner, i.e. did an extended period of gameplay lead to improved locomotor skills over the course of the action research period. Finally, in section 5.5, all findings are analysed and married in an attempt to answer the research question as a whole.

5.3 EVALUATION STRATEGY

5.3.1 EVALUATION 1: DESIGN AND DEPLOYMENT

At the beginning of the action research period, the researcher (in role as class teacher) deployed video games for locomotor acquisition to a relatively small cohort of four children aged between 5-6 years. These children participated in video games for locomotor acquisition on a daily basis over a two-week period. This initial period of video game deployment was conducted to trial, track and record the process of delivering PaCMAn through video gameplay in the classroom. A *deployment form* (appendix 2) was developed, to systematically record how each part of the PaCMAn design framework was delivered. Logistical considerations of the classroom were also tracked and recorded using this deployment form.

Completed deployment forms (appendix 2.1) were analysed to establish nuances of the deployment process and ultimately used to articulate a *Teacher Adaption and Deployment Guide*; an easy to follow rubric that supports teachers with independent deployment of video games for locomotor acquisition (outlined in this study), in their own classrooms. Important divisions about what the game does and what the teacher does, are also encapsulated within this guide. Teachers are then provided with an adaptable video game (Jump Ball) and a Teacher Adaption and Deployment Guide to facilitate the second part of the research question; concerned with an evaluation into the effectiveness of video games for locomotor acquisition from their (class teacher) perspective.

5.3.2 EVALUATION 2: EFFECTIVENESS FROM A TEACHER PERSPECTIVE

Four teachers were observed deploying video games for locomotor acquisition in their own classroom. Teachers were presented with (i) an Adaption and Deployment Guide and (ii) an adaptable Locogame; Jump Ball. The game and Kinect sensor was set-up for them. Teachers were encouraged to move through the steps outlined in the guide and deploy the video game for locomotor acquisition (Jump Ball) with a child in their class. Teachers received minimal assistance from the researcher and were encouraged to share their thoughts and feedback before, during and after this deployment process. Teacher deployment experiences (n=4) were video recorded, audio recorded and photographed then transcribed into deployment forms (appendix 2.2). Completed forms were used to speak to the effectiveness of video games for locomotor acquisition in the classroom from the teacher's perspective.

5.3.3 EVALUATION 3: EFFECTIVENESS FROM A LEARNER PERSPECTIVE

The final evaluation was concerned with the affect video games for locomotor acquisition had on user performance. In total, 52 senior infant children were exposed to video gameplay on a daily basis over a period of 8 weeks. A strict schedule was devised (appendix 3) to structure practice and gameplay and ensure four locomotor skills were targeted in a blocked yet variable manner, in equal measure. As a teacher in the school, the researcher had additional information relating to the cohort. For example, several children were members of a local football team or held a diagnosis of ADHD/ASD. Results from these children could potentially skew data relating to the effectiveness of the intervention (video games for locomotor acquisition) as perceived improvement or non-improvements could be attributed to the additional motor training platform (football) or an underlying condition that affects motor acquisition (ADHD/ASD). Consequently, four children took part in the study but their results were excluded from analysis; this left 48 typically developing children.

Locomotor acquisition of the cohort was assessed at three points; pretest, interim test (week 4) and posttest (2 weeks after the action research period concluded). The posttest was delayed in order to account, in some way, for retention. To date, findings from motor assessments have proved counter-intuitive (Lee & Schmidt, 2008). For example, training programs are often observed to be effective during deployment i.e. children appear to improve performance as they 'practice', but fail to demonstrate these same gains away from practice situations. Locomotor acquisition is tested using the TGMD-2 (Ulrich, 2000), a popular, standardised gross motor assessment tool that assesses the locomotor skills of children aged 3-10 years by evaluating the 'performance criteria' of each skill. A child is given 1 point for criteria they are deemed to pass and 0 for criteria they are deemed to fail. Performance criteria are added together to ascertain the total *score* for each skill. The scores of each skill are added together to attain an overall locomotor acquisition score. High scores indicate well developed locomotor skills. Sample TGMD-2 results can be found in appendix 4. This study utilises a paradigm that measures 5 locomotor skills, run, hop, skip, jump and slide with a potential maximum score of 40 points. The assessment rubric for a skip was obtained from the TGMD-1

(Ulrich, 1985) as it was not included in the second edition. Skipping was deemed important in this study as it was the locomotor skill that initially prompted this research (i.e. the majority of children in the researcher's own infant class, 2011-2012, demonstrated an inability to skip). O'Brien et al. (2014) also found that the jump and skip locomotor skills, proved the most difficult for (Irish) adolescents to perform.

A normal distribution of the cohort was informed based on internal/external information, pretests and previous assessments. A paired sample T-Test was utilised to determine whether significant differences existed in locomotor skills from pretest to posttest. SPSS software (ver. 20.05) was employed to analyse data. P<0.05 was considered significant. The layout of this final quantitative part of action research is illustrated below (figure 5.1).

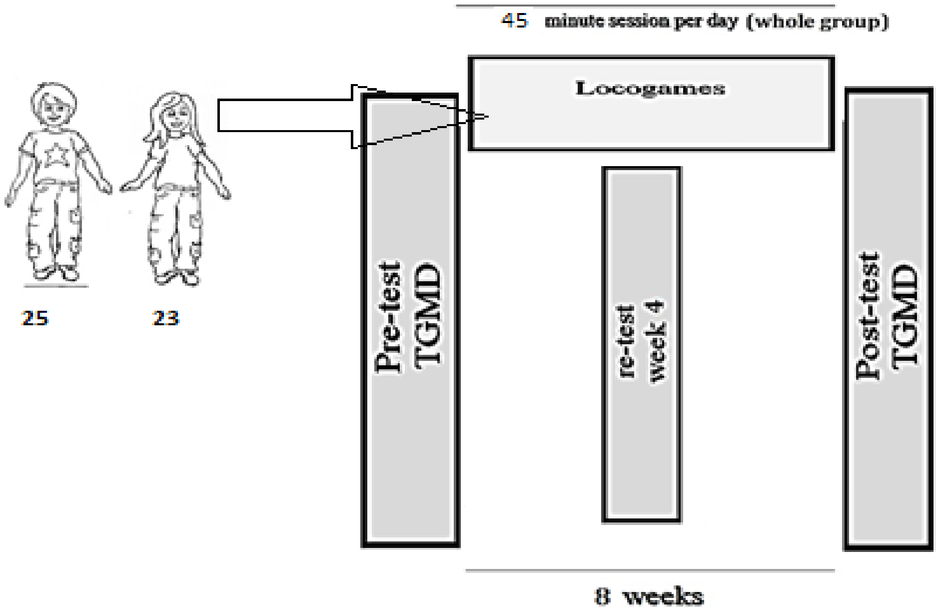


FIGURE 5.1 LAYOUT OF QUANTITATIVE APPROACH

5.4 RESULTS OF EVALUATION

5.4.1 RESULTS OF EVALUATION 1: DESIGN AND DEPLOYMENT

PaCMAn (Principles and Conditions for Motor Acquisition), the motor training and acquisition framework, was outlined in chapter 3. This framework is intended to underpin every aspect (design, development and deployment) of video games for locomotor acquisition. However, the delivery of PaCMAn in a video gaming environment requires significant attention. Furthermore, several principles and conditions are 'virtually' impossible to support owing to 3D sensor technical limitations. However, these limitations are potentially negotiated by a *human adaptive component*, the teacher, who is called upon to facilitate parts of PaCMAn that the game cannot. With this model, teachers need to know what is expected of them. Essentially, they require a guide to deployment that allows for a consistent delivery of PaCMAn through video games in the classroom. The articulation of a guide requires rigorous evaluation, first to explicitly classify **who** delivers each motor learning principle and condition, and then decipher both **how** and **when** these principles are delivered. After this, the results can be used to illustrate and articulate a *Teacher Adaption and Deployment Guide* (presented at the close of this section, figure 5.4, beginning on page 93).

We know that PaCMAn is delivered in video games for locomotor acquisition through an adaptive process between game and teacher. Everything the teacher has to do, during this deployment process, was recorded by the researcher (in role as teacher) at the beginning of the action research period. As such, video games for locomotor acquisition in the classroom were initially deployed over two weeks, with four users of mixed ability. Details of this deployment process were tracked using *deployment forms.* Completed deployment forms (appendix 2.2) will now be untangled to classify **who** delivers each principle/condition (table 5.1) and then, to illustrate the means of deployment, i.e. **how** and **when** each principle and condition is delivered (table 5.2). Nuances of this delivery are also discussed. Following this, a deployment form is transcribed to present a specific outline and **case example** of the deployment process (table 5.3). Finally, the results of the previous are all used to inform the articulation of **Teacher Adaption and Deployment Guide.** This 'step process' towards a deployment guide is illustrated below (figure 5.2).

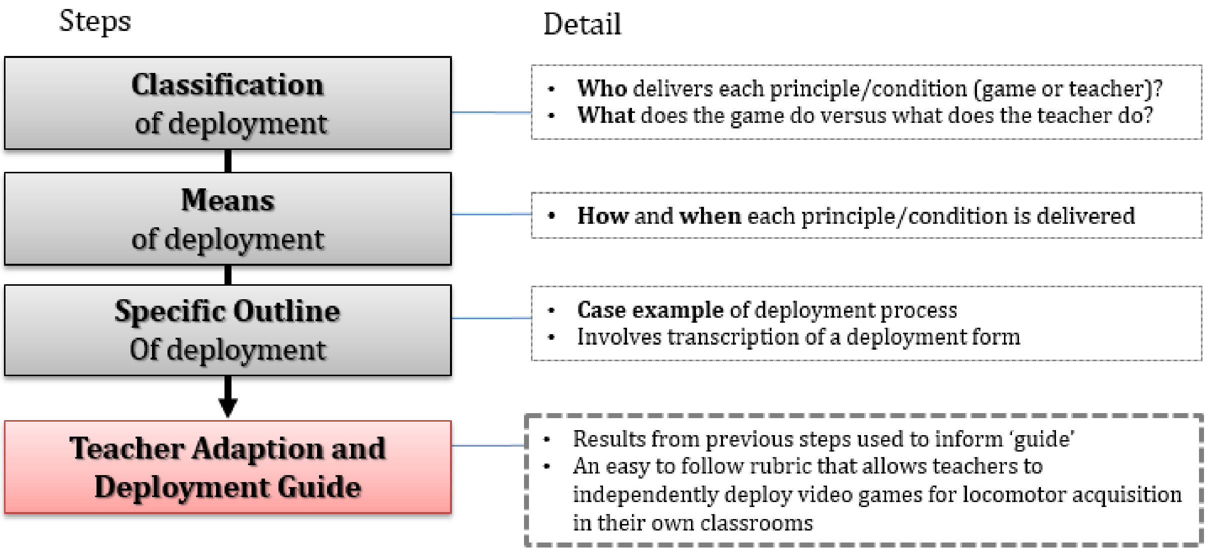


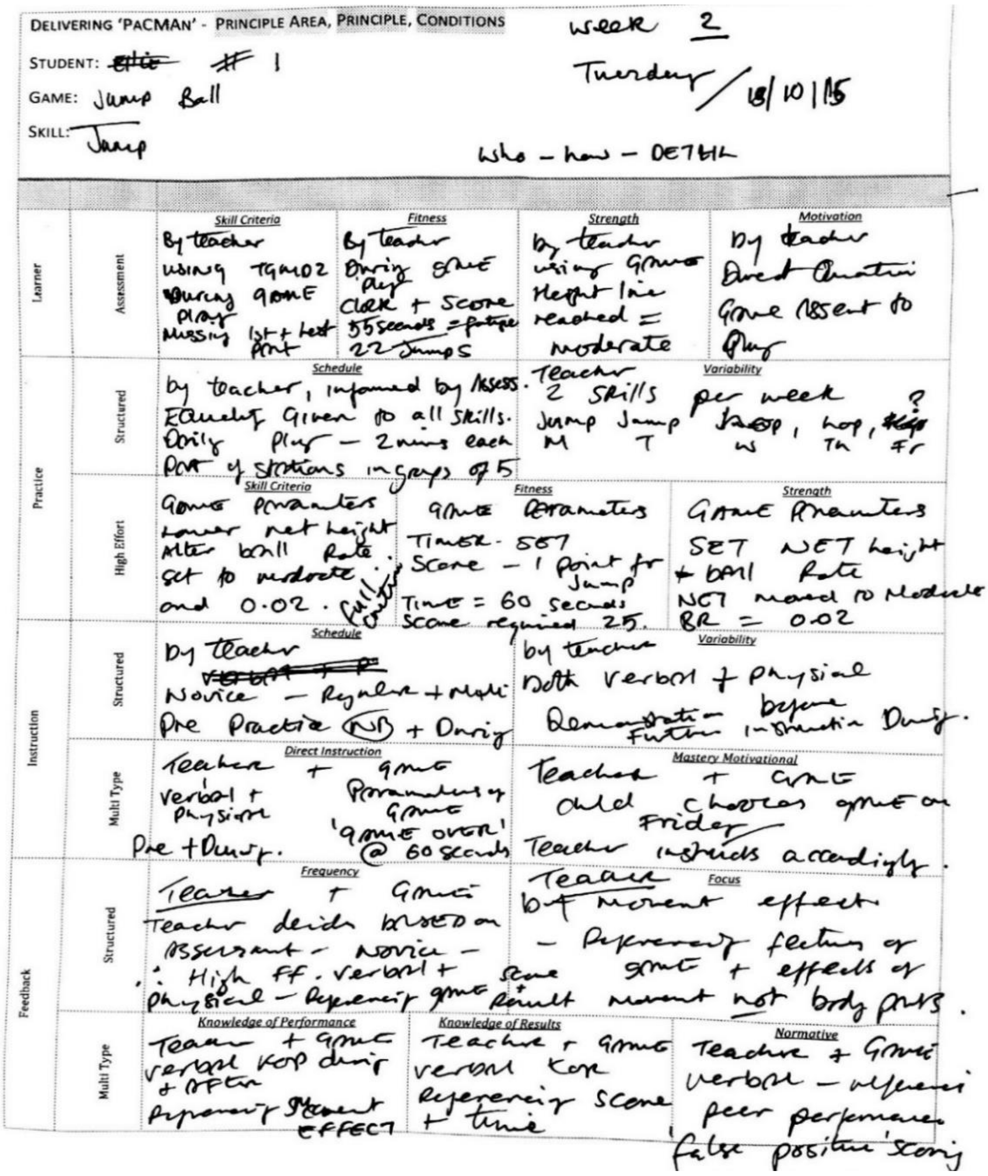
FIGURE 5.2 STEPS TOWARDS THE ARTICULATION OF TEACHER ADAPTION AND DEPLOYMENT GUIDE

Classification of Deployment

An analysis of deployment forms (appendix 2.2) reveals every principle and condition, within the PaCMAn framework, **can** be supported through video gameplay in the classroom.

Further, the delivery of these motor learning principles and conditions is consistent irrespective of the game (hop ball, jump ball, slide ball, skip attack) or the individual characteristics of the learner (strong or weak baseline locomotor skills). Deployment forms have been analysed to classify which principles are supported by the **teacher** and which principles are supported by the **game**. Findings indicate that, whilst several PaCMAn are predominantly delivered by the teacher more than the game (and vice versa), overall, PaCMAn is delivered through a unique deployment process dependent on a marriage between the two (game and teacher).

A sample deployment form is presented below (figure 5.3), this is followed by a classification and outline of **who** delivers each principle (table 5.1).



DELIVERING 'PACMAN' - PRINCIPLE AREA, PRINCIPLE, CONDITIONS

week 2

STUDENT: [redacted] # 1

Tuesday / 13/10/15

GAME: Jump Ball

SKILL: Jump

who – how – DETAIL

Learner	Assessment	*Skill Criteria* By teacher using TGMD2 during game play Missing 1st + last point	*Fitness* By teacher during game play Clock + score 55 seconds = fatigue 22 jumps	*Strength* by teacher using game Height line reached = moderate	*Motivation* by teacher Direct Question Game Absent to Play
Practice	Structured	*Schedule* by teacher, informed by Assess. Equally given to all skills. Daily play – 2 mins each Part of stations in groups of 5		*Variability* Teacher 2 skills per week ? Jump Jump Leap, hop, ~~Skip~~ M T W Th Fr	
	High Effort	*Skill Criteria* Game Parameters Lower net height Alter ball Rate. set to moderate ∴ Full Control and 0.02.	*Fitness* game Parameters TIMER - SET Score – 1 point for Jump Time = 60 seconds Score required 25.	*Strength* GAME Parameters SET NET height + ball Rate NET moved to Moderate BR = 0.02	
Instruction	Structured	*Schedule* by teacher ~~Verbal + P~~ Novice – Regular + Multi Pre Practice (NB) + During		*Variability* by teacher both verbal + physical Demonstration before Further instruction During.	
	Multi Type	*Direct Instruction* Teacher + game verbal + physical Pre + During. Parameters of Game 'game over' @ 60 seconds		*Mastery Motivational* Teacher + Game child chooses game on Friday Teacher instructs accordingly.	
Feedback	Structured	*Frequency* Teacher + Game Teacher decides based on Assessment – Novice – ∴ High FF. verbal + physical – referencing game + score result		*Focus* Teacher b+f movement effect. – Referencing features of game + effects of movement not body parts.	
	Multi Type	*Knowledge of Performance* Teacher + game verbal KOP during + after referencing movement EFFECT	*Knowledge of Results* Teacher + game verbal KOR referencing score + time	*Normative* Teacher + Game verbal – referencing peer performance 'false positive' scoring	

FIGURE 5.3 SAMPLE DEPLOYMENT LOG

TABLE 5.1 CLASSIFICATION OF DEPLOYMENT: WHO DELIVERS PACMAN

<table>
<tr><td colspan="14">DELIVERING 'PACMAN' - PRINCIPLE AREA, PRINCIPLE, CONDITIONS
STUDENT: #1
GAME: JUMP BALL **SKILL**: JUMP</td><td colspan="3">**CLASSIFICATION**
WHO DELIVERS EACH PRINCIPLE</td></tr>
<tr><td>🟫</td><td>🟩</td><td colspan="12">🟦</td><td>*Teacher*</td><td>Game</td><td>Teacher with Reference to Game Design Features</td></tr>
<tr><td>**Learner**</td><td>Assessment</td><td colspan="3">*Skill Criteria*
Assessed by **Teacher**
Facilitated by **game**play</td><td colspan="3">*Force*
Assessed by **Teacher**
Facilitated by **game** features (height lines)</td><td colspan="3">*Fitness*
Assessed by **Teacher**
Facilitated by **game** features (timer)</td><td colspan="3">*Motivation*
Assessed by **Teacher** (verbal assent)</td><td></td><td></td><td>✓</td></tr>
<tr><td rowspan="2">**Practice**</td><td>Structured</td><td colspan="6">*Schedule*
Devised by **Teacher**</td><td colspan="6">*Variability*
Assigned by **Teacher**</td><td>✓</td><td></td><td></td></tr>
<tr><td>High Effort</td><td colspan="4">*Skill Criteria*
Determined by Adapted **Game** Design Features</td><td colspan="4">*Fitness*
Determined by Adapted **Game** Design Features</td><td colspan="4">*Strength*
Determined by Adapted **Game** Design Features</td><td></td><td>✓</td><td></td></tr>
<tr><td rowspan="2">**Instruction**</td><td>Structured</td><td colspan="6">*Schedule*
Devised by **Teacher**</td><td colspan="6">*Variability*
Devised by **Teacher**</td><td>✓</td><td></td><td></td></tr>
<tr><td>Multi Type</td><td colspan="6">*Direct Instruction*
Delivered by **Teacher** with Reference to **Game** Design Features</td><td colspan="6">*Mastery Motivational*
Supported by **Teacher** with Reference to **Game** Choice</td><td></td><td></td><td>✓</td></tr>
<tr><td rowspan="2">**Feedback**</td><td>Structured</td><td colspan="6">*Frequency*
Supported by **Teacher** with Reference to **Game** Design Features</td><td colspan="6">*Focus*
Supported by **Teacher** with Reference to **Game** Design Features</td><td></td><td></td><td>✓</td></tr>
<tr><td>Multi Type</td><td colspan="4">*Knowledge of Performance*
Delivered by **Teacher** with Reference to **Game** Design Features</td><td colspan="4">*Knowledge of Results*
Delivered by **Teacher** and **Game** Features (e.g. score)</td><td colspan="4">*Normative*
Delivered by **Teacher** with support from **Game** Design Features</td><td></td><td></td><td>✓</td></tr>
</table>

Table 5.1 highlights the importance of an adaptive process required between game and teacher to deliver PaCMAn through video gameplay in the classroom. It represents a *macro* outline of what principles the teacher is expected to deliver, what principles the games can deliver and what principles require a unique deployment process between the two.

Means of Deployment

Further *micro* detail relating to **how** and **when** these principles are delivered also need to be deciphered. These details were also extracted from an analysis of user deployment forms. Findings are presented below in table form (table 5.2). They provide an additional step towards the articulation of Teacher Adaption and Deployment Guide.

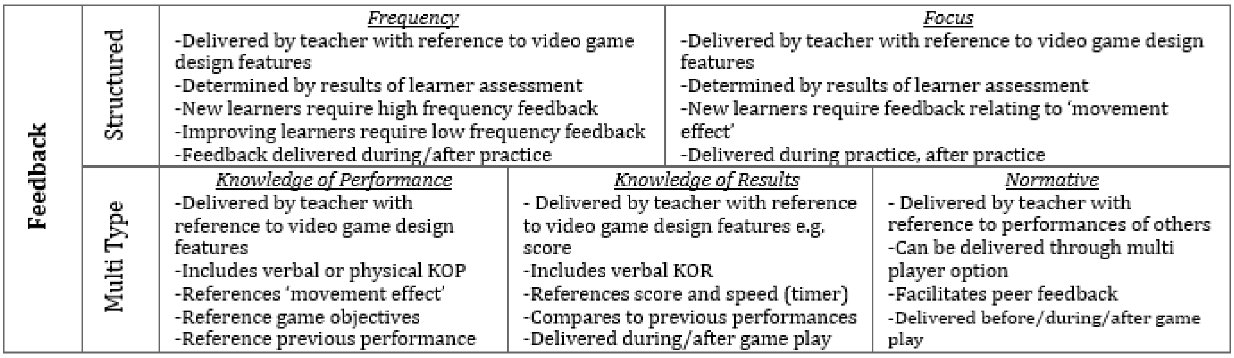
TABLE 5.2 HOW AND WHEN PACMAN IS DELIVERED

DELIVERING 'PACMAN' - PRINCIPLE AREA, PRINCIPLE, CONDITIONS
STUDENT: #1
GAME: JUMP BALL
SKILL: JUMP

Learner	Assessment	*Skill Criteria* -User skill criteria assessed by teacher during 'practice trial' -A 'practice trial' is also used to allow the user a trial run at gameplay before their score is officially counted	*Strength* -Assessed by teacher who montiors game features e.g height lines - The height line reached by the game character reveals 'force' (height of jump performed by user) -Recorded during a 'practice trial'	*Fitness* - Assessed by teacher by montioring game features e.g. timer and scoreboard -Timer tracks point of fatigue -Score tracks number of jumps -Results indicate how many jumps a user can perform before fatigue sets in -Recorded during a 'practice trial'	*Motivation* -Assessed by teacher through direct questioning "Would you like to play this game?". -Observed effort during practice trial i.e. low effort indicates decreased motivation -Recorded before and during practice trial

Practice	Structured	*Schedule* -Determined by teacher before gameplay -Daily practice where possible -Game play fits within curriculum parameters	*Variability* -Determined by the teacher before gameplay -Different games support acquisition of different skills jump, hop, skip & slide -Choice of game depends on needs of the child e.g. Hop Ball to improve hopping, Jump Ball to improve jumping etc.	
	High Effort	*Skill Criteria* -Determined through teacher adaption of target height i.e. low, moderate or high net elicits parts of the skill or full criteria -Adaption carried out before gameplay	*Fitness* -Determined through teacher adaption of timer -Set 'game over' to suitable time, depending on result of learner assessment i.e. recorded point of fatigue -Teacher instructs child to score a number of points in line with assessment results -Timer adapted before gameplay -Specific score requested before gameplay	*Strength* -Determined through teacher adaption of target - Net height adapted in line with user assessment -High net for strong jumper, moderate net for moderate jumper, low net for weak jumper -Adaption of target height takes place before gameplay

Instruction	Structure	*Schedule* -Determined by teacher using results of learner assessment -New learners require pre-practice demonstrations and instruction during practice -Improved learners require less instruction -Determined before gameplay	*Variability* -Determined by teacher using results of learner assessment -Mixed provision of demonstration, direct instruction and mastery motivational instruction is suitable for novice learners -Determined before gameplay
	Multi Type	*Direct Instruction* -Delivered by teacher with reference to video game design features -Includes verbal and/or physical demonstration -References previous performance -Delivered before and during gameplay	*Mastery Motivational* -Facilitated by teacher before gameplay -Offers user the choice of game they would like to play -The chosen game is then adapted by teacher to suit individual needs



Feedback	Structured	*Frequency* -Delivered by teacher with reference to video game design features -Determined by results of learner assessment -New learners require high frequency feedback -Improving learners require low frequency feedback -Feedback delivered during/after practice	*Focus* -Delivered by teacher with reference to video game design features -Determined by results of learner assessment -New learners require feedback relating to 'movement effect' -Delivered during practice, after practice	
	Multi Type	*Knowledge of Performance* -Delivered by teacher with reference to video game design features -Includes verbal or physical KOP -References 'movement effect' -Reference game objectives -Reference previous performance	*Knowledge of Results* - Delivered by teacher with reference to video game design features e.g. score -Includes verbal KOR -References score and speed (timer) -Compares to previous performances -Delivered during/after game play	*Normative* - Delivered by teacher with reference to performances of others -Can be delivered through multi player option -Facilitates peer feedback -Delivered before/during/after game play

The delivery of PaCMAn is generally principle specific. That is, we can loosely state who delivers each principle (teacher/game/both) depending on the principle. For example, the first principle, *Learner Assessment*, is delivered mainly by the teacher who is expected to assess user performance during gameplay. However, this process is facilitated by several game design features e.g. height lines, timer, score etc. Essentially, a baseline user assessment is carried out during a 'practice trial' which is portrayed to the user as an opportunity to practice. Instead, this 'practice trial' presents as an opportunity for the teacher to assess skill criteria, fitness and force of locomotor outputs performed by the user. The user is prompted to perform at least a dozen consecutive outputs which allows skill criteria to be fairly assessed. The *force* (height or width) of a skill is ascertained by examining the 'height line' reached by the game character on average (low, moderate or high). Fatigue is measured by noting the time on the 'game clock' when the user presents as fatigued. Fatigue can be identified through a sudden pronounced pause between outputs or a sudden inability to reach the target. The score at the point of fatigue reflects the number of jumps the user can perform before reaching exhaustion, e.g. 18 points on the score board when the user presents as fatigued, signifies that their current fitness level is 18 consecutive jumps. In all, a 'learner assessment' is delivered by the teacher but *facilitated* through gameplay and game design features.

The second principle, which refers to the need for *Structured Practice* is also delivered by the teacher. For example, the 'practice schedule' (e.g. daily practice), 'practice variability' and 'practice distribution' should be in accordance with results of the learner assessment. That is, if a learner tests as lacking more *jump* criteria compared to hop criteria, the schedule should reflect this need for additional time on the jump skill thus, in a week, the user might spend two days playing Hop Ball (hopping) and three days playing Jump Ball (jumping). Given that the practice schedule is concerned with the amount of gameplay and practice variability is concerned with which game is played, practice is structured by the teacher but *facilitated* by the games.

The third principle, relating to *High Effort,* is more dependent on an adaptive process between teacher and game. Appropriate effort is facilitated through length of gameplay. Put simply, if a user fatigues at 55 seconds during an assessment trial, gameplay should end near that same time. The length of play (duration) is therefore determined by the teacher during an assessment, who then adapts the timer to meet the individual user's point of fatigue. The skill criteria a user is expected to perform also equates to the level of effort. That is, if a user fails to perform any jump criteria correctly then they should first work on the skill *in parts*. Skill criteria expected of the user is determined by the position of a target. For example, in Jump Ball, a high net requires the user to perform a whole jump with full criteria. In contrast, a low net requires the user to perform the first two parts of a jump only. Similarly, the strength of a user's outputs (height of a jump, width of a slide etc.) is also determined by the position of a target. Ultimately, game targets are adapted by the teacher. *High Effort* during gameplay is thus, dependent on a human adaptive component to adjust game design features (scores, timers, targets) in line with user fitness, force and skill level. The adaptive process is ultimately informed by the learner assessment carried out during a preliminary game or 'practice trial'.

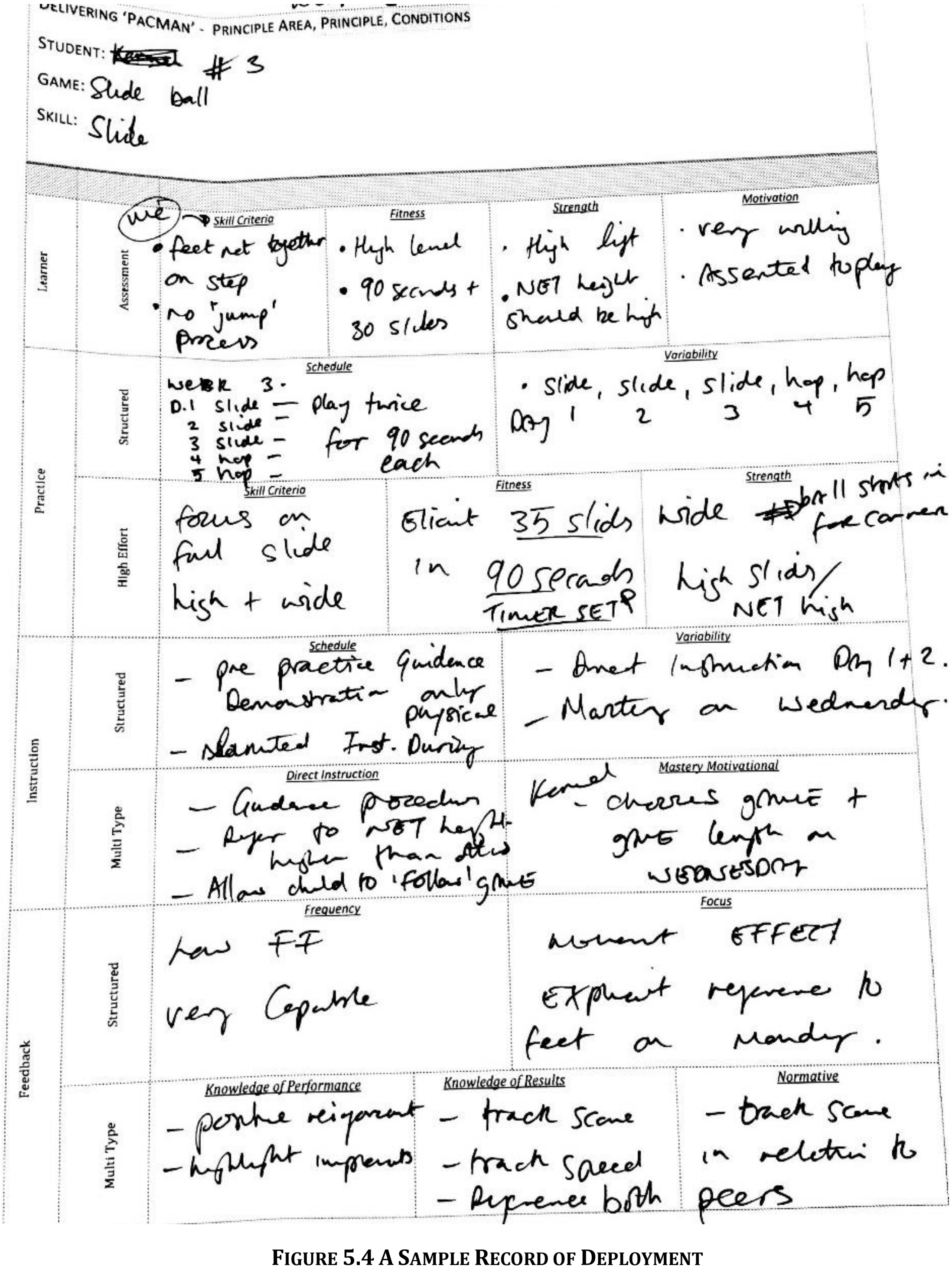
Remaining principles relating to instruction and feedback are largely delivered by the teacher but often with specific reference to game objectives and design features. A *Structured Instructional Approach* (fourth principle of PaCMAn) is reliant on the teacher to determine an instructional 'schedule' based on the type of learner. For example, novice learners require concurrent instruction that is delivered randomly before, during and after gameplay. Novice learners also require a multi-instructional approach including direct instruction and pre-practice demonstrations (verbal and/or physical). These instructional approaches often reference game objectives and design features e.g. "I want you to get right down to the red line, then reach up high to get the ball in the net". Conversely, a 'mastery motivational' approach is delivered by allowing users to choose the game *they* want to play. In all, principles and conditions related to instruction are delivered by the teacher with continuous reference to the game, its features and its objectives.

Feedback is delivered during gameplay through rolling scores, flashing targets and sound effects that let a user know if they have been successful (knowledge of results). However, the user often needs the teacher to bring this feedback to life. Essentially, a user can be too pre-occupied concentrating on motor outputs to observe their score or the amount of time they have left to play. Thus, users benefit from receiving verbal prompts from the teacher who provides knowledge of results (referencing score and time etc.) and knowledge of performance (referencing the output); e.g. "you're doing so well, you already have 12 points with 10 seconds left" (KOR) and "keep those jumps nice and high, stretch right up to the net" (KOP). Feedback from game design features can be hidden/muted by the teacher as the user becomes more proficient. The frequency of feedback from the teacher can also be reduced or increased to meet individual learner needs. Overall, feedback is delivered by the teacher and the game. Feedback typically involves a process of verbally referencing game features and objectives, depending on user needs.

Ergo, PaCMAn *is* deliverable in a gaming environment. Its delivery calls for an adaptive process between the teacher and the game. A breakdown of this process has included (i) classification of **who** delivers each principle/condition (game, teacher or both) and (ii) finer details relating to the means of deployment, i.e. **how** and **when** these principles are delivered.

Specific Outline of Deployment

A specific outline of how video games for locomotor acquisition in the classroom are deployed will now be presented as a **Case Example**. This example comes directly from the transcription of a *sample deployment form* (figure 5.4, below). Results are outlined in table 5.2 (following page). This represents a final step towards the articulation of a Teacher Adaption and Deployment Guide.



DELIVERING 'PACMAN' - PRINCIPLE AREA, PRINCIPLE, CONDITIONS

STUDENT: [redacted] # 3

GAME: Slide ball

SKILL: Slide

Learner	Assessment	*Skill Criteria* we • feet not together on step • no 'jump' process	*Fitness* • High level • 90 seconds + 30 slides	*Strength* • High lift • NET height should be high	*Motivation* • very willing • Assented to play
Practice	Structured	*Schedule* Week 3. D.1 slide – play twice 2 slide – 3 slide – for 90 seconds each 4 hop – 5 hop –	*Variability* • Slide, slide, slide, hop, hop Day 1 2 3 4 5		
	High Effort	*Skill Criteria* focus on full slide high + wide	*Fitness* Elicit 35 slides in 90 seconds TIMER SET?	*Strength* wide ~~#~~ ball starts in far corner high slides/ NET high	
Instruction	Structured	*Schedule* – pre practice Guidance Demonstration only physical – Slanted Inst. During	*Variability* – Direct Instruction Day 1+2. – Mastery on Wednesday.		
	Multi Type	*Direct Instruction* – Guidance procedure – Refer to NET height higher than others – Allow child to 'follow' game	*Mastery Motivational* Kemal – chooses game + game length on WEDNESDAY		
Feedback	Structured	*Frequency* Low FF very Capable	*Focus* Movement EFFECT Explicit reference to feet on Monday.		
	Multi Type	*Knowledge of Performance* – positive reinforcement – highlight improvements	*Knowledge of Results* – track score – track speed – Reference both	*Normative* – track score in relation to peers	

FIGURE 5.4 A SAMPLE RECORD OF DEPLOYMENT

TABLE 5.3 CASE EXAMPLE: THE DEPLOYMENT OF VIDEO GAMES FOR LOCOMOTOR ACQUISITION

CASE EXAMPLE

WEEK 3 STUDENT: #3 GAME: SLIDE BALL SKILL: SLIDE

Learner Assessment

Absent Criteria
Step sideways and slide both feet together ✗
Both feet momentarily of the ground ✗
Fitness:
High level of fitness. Fatigued at **90 seconds** following **35 slide** (35 points on scoreboard)
Strength
Slides were high and child was able to squat under low wall

Practice Goals

1. Work on absent criteria within whole skill performance
2. Practice for 90 seconds and elicit between 35-40 whole slides.
3. Achieve 35 points (1 point for each slide performed)
4. Set net height to 'high' to elicit high slide point
5. Set wall height to 'low' to elicit low squat

Practice

-*Structure*
Schedule: play twice daily, for 90 seconds per trial, with 5 minutes resting time. Two skills per week, working on slide (slide ball) Monday & Tuesday then hopping (hop ball) Wednesday & Thursday
-*High Effort*
Skill criteria: Net set to high, to elicit full criteria and high slide point.
Fitness: 'Game over' to appear at 90 seconds.
Strength: Wall set to low, to elicit low squat. Points system set to 1 point per score.

Instruction

-*Structure*
Schedule: pre practice physical demonstration and verbal demonstration of skill and game objectives. Provide further instruction during play (concurrent)
Variability: mainly direct instruction, mastery motivational instruction on Friday
-*Multi Type Instruction*
Direct Instruction: Physical demonstration of slide performed by teacher. Verbal demonstration that focuses on absent criteria. Student encouraged to score 35 points. Student told that the game will end after 90 seconds
Mastery Motivational Instruction: Student chooses game they want to play on Friday

---

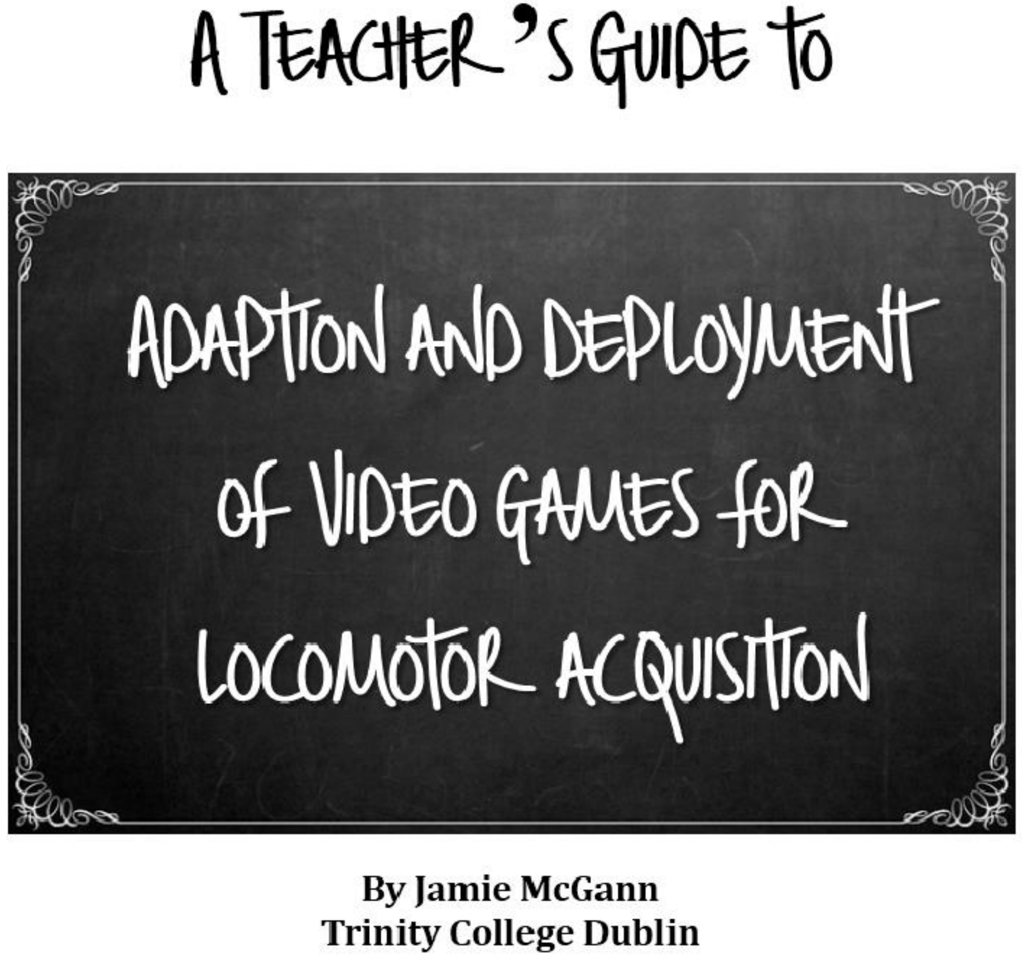
Feedback

-*Structure*
Frequency: High feedback frequency as student is a novice learner
Focus: Concentrate on movement effect, trying not to reference body parts specifically. "I want to hear a click" elicits feet coming together. "Get low under that wall", elicits deep squat.
-*Multi Type Instruction*
Knowledge of Performance: Verbally delivered, "I hear the click of the heels", "that's a great slide", "That's a good rhythm", "that's nice and high". Follows successful outputs. Positive reinforcement.
Knowledge of results: Verbally delivered by teacher, reference KOR available from game. "You have 20 seconds left", "You're already on 30 points", "You're doing better than your last time".
Normative: Reference scores of other children. Encourage other children to keep track of score. Allow at least one trial for multi-player

The previous findings have given an insight into how PaCMAn is delivered through video gameplay in the classroom. We now know **who** is responsible for the delivery of each principle as well as **how** and **when** this delivery takes place. A specific outline followed with a case example of the deployment process. Following an analysis of all deployment forms (samples found in appendix 2.1), it becomes clear that the nuances of the deployment vary, only slightly, from one learner to another and that the overall *deployment of video games for locomotor acquisition in the classroom* is consistent across all games, for all users. Consequently, findings will now be utilised to articulate and illustrate **A Teacher Adaption and Deployment Guide**; a guide to assist teachers with the deployment of video games for locomotor acquisition in their own class.

Several iterations of the adaption and deployment guide existed before the finished version (presented in figure 5.4, over the following pages) was produced. Changes to the guide occurred after initial feedback from teachers revealed the first iteration to be too text heavy, too detailed and difficult to follow. The final draft consists largely of illustrations with snippets of script-like phrases to facilitate the delivery of optimal instruction and feedback. Illustrations and script-like text are characteristics also evident in the popular teacher's manual 'Ready, Set, Go, Maths' (Pitt, 2005) which is regularly used by teachers in the school where the action research took place. Pitt (2005) encourages teachers to use the manual 'on the go' during math class. In this way, the articulation and layout of Ready, Set, Go, Maths inspired the Teacher Adaption and Deployment Guide as it is also heavily illustrated, features snippets of scripted text and also aims to support 'on the go' and easy to follow instructions of deployment. The completed guide now follows.

FIGURE 5.5 TEACHER ADAPTION AND DEPLOYMENT GUIDE



A TEACHER'S GUIDE TO

ADAPTION AND DEPLOYMENT
OF VIDEO GAMES FOR
LOCOMOTOR ACQUISITION

By Jamie McGann
Trinity College Dublin

1. ASSESSMENT OF LEARNER USING 'JUMP BALL'

Skill Criteria	Knees bent, arms behind body	
	Arms extended forward and upward above the ahead	
	Take off and land on both feet simultaneously	
	Arms brought forcefully down towards feet	

Whole Skill
If the learner can perform any part of the skill
Focus on absent criteria as part of a whole skill performance

Parts & Progression
If all criteria is absent and skill level is '0'
First, practice the skill in parts and progress to whole skill

Strength	Look at height of Jump		
	Low	🟨	
	Moderate	🟦	
	High	🟥	

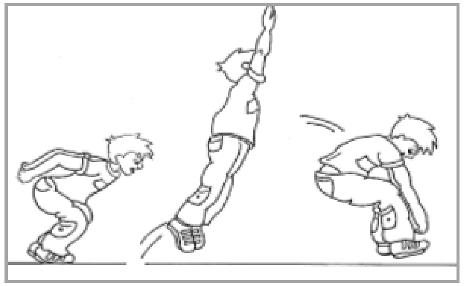
Set the net height to reflect strength of the learner

Fitness	How many consecutive Jumps before exhaustion? ***Subtract c.5 for Ideal High Effort**	
	How many seconds have passed? ***Subtract c.10 seconds for Ideal High Effort**	

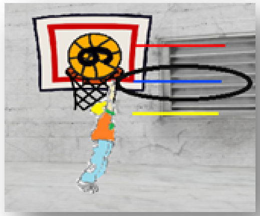
Set timer to reflect Capability of the learner.

RESULTS ON PRACTICE

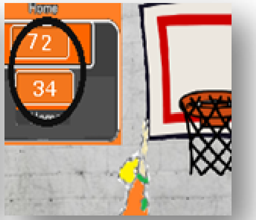
Criteria to be worked on in:
-Whole Skill ☐
or
-Parts & Progression ☐



Current Level
- Jumps are ___________height
- ____ Jumps in a row
- Time ______ seconds



STRENGTH



FITNESS

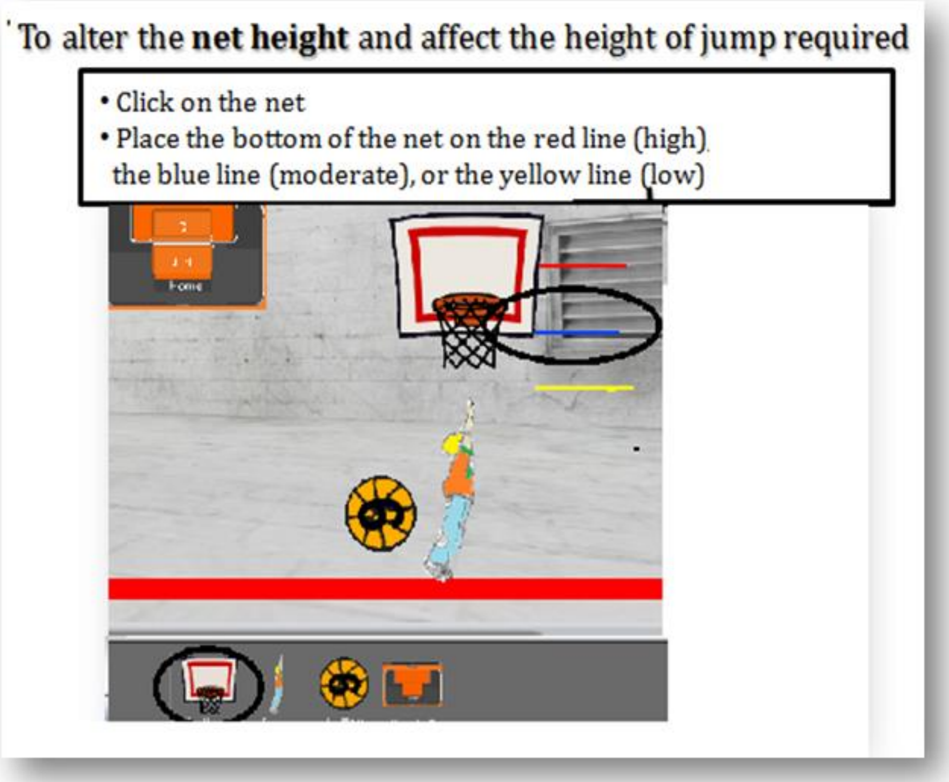
2. SET GAME PARAMETERS (BASED ON RESULTS)

Depending on User Fitness
•Set timer to _____ seconds

Depending on user strength
•Set net height to ______ line

To **Change the timer** and alter the length of the game:

- Click on the boy at the bottom of the screen
- Click on the 'scripts' tab
- Click on the '60' and type in the number of seconds you wish the game to last



To alter the **net height** and affect the height of jump required

- Click on the net
- Place the bottom of the net on the red line (high) the blue line (moderate), or the yellow line (low)

3. PROVIDE INSTRUCTION BEFORE GAME PLAY

VERBAL

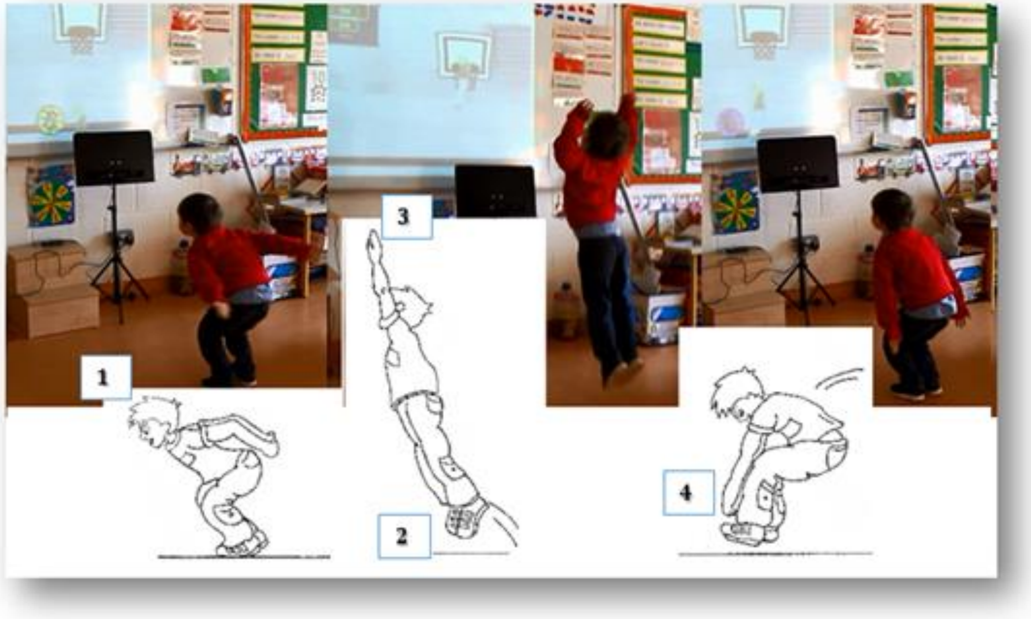
Direct Instruction

Teacher: *I want you to pick up the basketball from the red line and get it up to the basketball net.*

Teacher: *This is how you pick up the ball.*
1. *Bend both knees and reach behind your body*
This is how you put the ball in the net
2. *Bring your arms forward and up*
3.*Take off and land on both feet*
4. *Bring your arms downwards when you land*

Teacher: *When the ball goes in the net, you will get _____ point(s).*
I want you to score ________ points.
You have ____seconds to do this, so be fast and don't give up!

PHYSICAL



4. FEEDBACK & INSTRUCTION: FOR NOVICE LEARNERS

MULTI TYPE INSTRUCTION

Direct Instruction	Mastery Motivational
Pre-practice physical and verbal demonstration. Repeat goals regularly, during task **Teacher**: *Pick up the ball, put it behind you, get high up to the net. Quick, pick up the ball again.*	Allow child to choose what game they would like to play, once a week

MULTI TYPE FEEDBACK

Knowledge of Results	Knowledge of Performance
The learner needs to know how successful they are. Let them know how well they are jumping, what their score is, how fast they are etc. **e.g. Teacher:** *You are already at 3 points, that is more than last time.*	Delivered verbally, relates to the performance of the skill (jump). Use after successful jump **e.g. Teacher:** *I liked the way you really stretched high*

STRUCTURED INSTRUCTION

Schedule	Variability
Deliver a physical and verbal demonstration of skill and game objectives Prior to practice Provide further direct instruction during play.	Use mainly direct instruction with mastery motivational approaches every so often

STRUCTURED FEEDBACK

Frequency	Focus
High frequency of feedback Before, during and after trials	Try not to discuss the parts of the child's body (arms, head, feet). ***Teacher:*** *Get down to the ball* (elicits knee bend) . Reach high up to the net (elicits arm stretch) etc.

MAINTAIN MOTIVATION LEVELS OF THE USER

LEARNER ASSESSMENT

Motivation	
Does the child want to play game?	
Yes	
Neutral	
No	

If child presents as **unmotivated**:

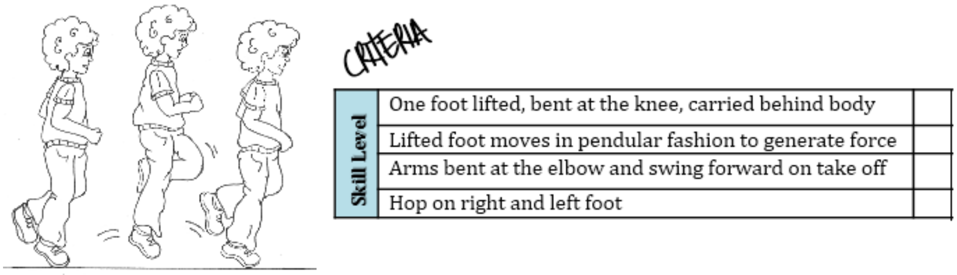
- Ensure **practice effort** is accurate - just outside the comfort zone but not so far as to cause panic
- Deliver additional instruction and feedback to instil confidence.
- Provide feedback after successful attempts only
- Deliver normative feedback by using **false positives** – i.e weak child receives 3 points per basket whilst a more able child receives 1 point.
- Increase Mastery Motivational approach
- Allowing child to choose the game they would like to play more regularly

```
if <touching ballnet ?>
  hi
  change score by 2
  play sound WaterDrop
  wait 1 secs
  go to x: 6 y: -141
  point towards Jump
  switch to costume (pick random 1 to 1
  show
  go to front
```

*** To change score per basket-**
Click on ball
Click on scripts
Scroll down to 'Change Score by' and type 1,2,3,4 etc.
Denotes points per basket.

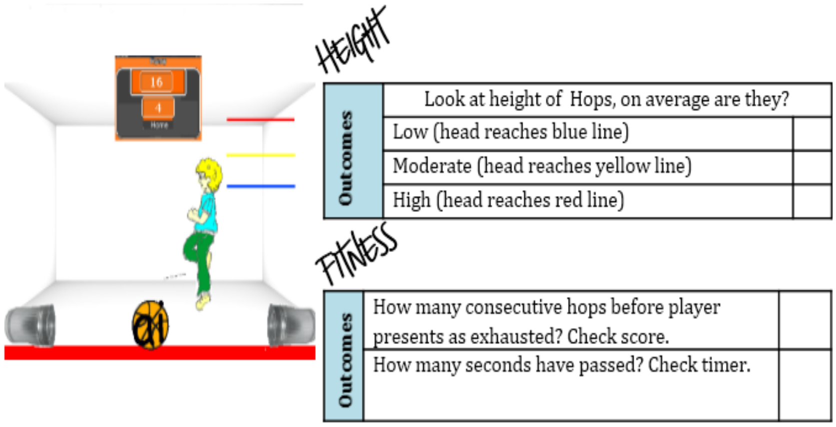
GOOD LUCK ☺

The Teacher Adaption and Deployment Guide opens with a learner assessment that differs to that of the TGMD-2 (Ulrich, 2000), the locomotor assessment tool typically used by teachers. Essentially, the user is assessed informally through game play during a 'practice trial' providing an outline of user needs. This informal assessment is supported in the guide by an original illustration and rubric for the assessment of locomotor process and product. The assessment borrows from TGMD-2 (Ulrich, 2000) as it looks for the presence of user 'skill criteria' (fig. 5.6) (process). Criteria is evaluated as children perform consecutive locomotor skills (hop, skip, jump, slide) during gameplay. Additional parameters not accounted for by the TGMD-2 (Ulrich, 2000) are also evaluated, namely (i) force (e.g. height of jump) and (ii) fitness (e.g. number of jumps before fatigue is evident). These parameters were tracked in a video game environment by monitoring the game design features such as 'timer', 'score' and 'height lines' (fig. 5.7). Results of the full assessment were utilised to inform adaption, feedback and instruction to meet individual user needs. The rubric for assessment outlined in the teacher's guide ultimately includes a re-articulation of criteria from the TGMD-2 (Ulrich, 2000) to assess skill process, accompanied by an original illustration of the skill. It also includes an original rubric for the assessment of skill *product*, which provides a unique opportunity to track and record parameters relating to strength and fitness typically difficult to assess in the real world. Ultimately, assessment proved to be a crucial part of the deployment process.



Skill Level	One foot lifted, bent at the knee, carried behind body	
	Lifted foot moves in pendular fashion to generate force	
	Arms bent at the elbow and swing forward on take off	
	Hop on right and left foot	

FIGURE 5.6 RUBRIC TO SUPPORT ASSESSMENT OF USER SKILL CRITERIA (PROCESS)



Outcomes	Look at height of Hops, on average are they?	
	Low (head reaches blue line)	
	Moderate (head reaches yellow line)	
	High (head reaches red line)	

Outcomes	How many consecutive hops before player presents as exhausted? Check score.	
	How many seconds have passed? Check timer.	

FIGURE 5.7 RUBRIC TO SUPPORT ASSESSMENT OF USER STRENGTH AND FITNESS DURING GAME PLAY

From a design perspective, video games for locomotor acquisition are multi-faceted. They require a theoretically informed framework (PaCMAn) which is then used to underpin game design. The delivery of PaCMAn in a game environment is deterred by technical limitations (including 3D sensor inaccuracies). Thus, video games for locomotor acquisition have to be adaptable in order to allow the teacher to deliver parts of the PaCMAn framework that the game could not. Thus, video games are deployed through an adaptive process between the teacher and the game. An overall outline of this deployment process is articulated in the **Teacher Adaption and Deployment Guide.**

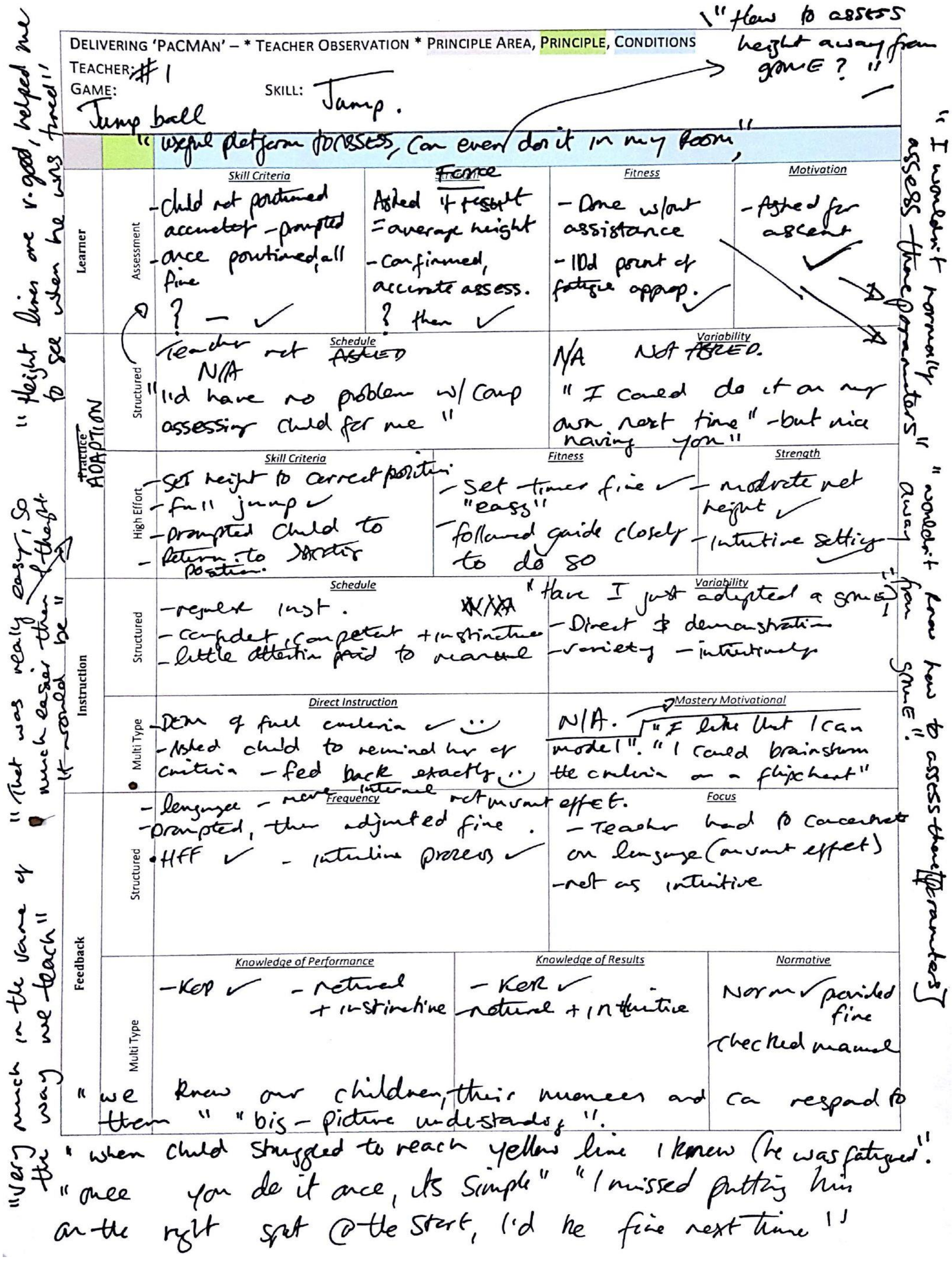
The next step is to evaluate the effectiveness of the deployment process, first from the point of view of the teacher i.e. are they capable of doing what is expected of them in the adaption and deployment guide; is the process practical for the classroom setting? Then, from the point of view of the learner i.e. does an extended period of gameplay facilitate improved locomotor skills? The following sections present results of this evaluation from the teacher's perspective (5.4.2) and learner's perspective (5.4.3).

5.4.2 RESULTS OF EVALUATION 2: EFFECTIVENESS OF DEPLOYMENT

This section provides results from a qualitative analysis of teacher experiences with the deployment of video games for locomotor acquisition in the classroom. The objective was to evaluate the 'effectiveness' of the deployment process from the teacher's point of view. Accordingly, four teachers were provided with a video game for locomotor acquisition (Jump Ball) and a *Teacher Adaption and Deployment Guide* (fig. 5.4). They were asked to follow the guide and deploy the game with one of the students in their class. Teacher experiences, feedback, comments and thoughts before, during and after the deployment process were video recorded (figure 5.8) and transcribed at runtime into deployment forms (appendix 2.2).

FIGURE 5.8 TEACHER DEPLOYMENT OBSERVATION

Completed deployment forms speak to the effectiveness of the deployment process from the teacher's point of view. A completed form of teacher #1's experience follows (figure 5.9). The experience documented in this form proved 'typical' for all teacher experiences. Since the deployment process was largely sequential, it was naturally tackled and discussed by the teachers in parts; beginning with **assessment** of user, followed by **adaption** then **instruction** and concluding with **feedback.** Whilst the deployment experience was similar for all teachers, individually they provided some unique insights, thoughtful suggestions and interesting feedback that could be utilised to enhance the deployment process in the future.



DELIVERING 'PACMAN' – * TEACHER OBSERVATION * PRINCIPLE AREA, PRINCIPLE, CONDITIONS

TEACHER: #1

GAME: Jump ball

SKILL: Jump.

" useful platform for assess, can even do it in my room, "

"How to assess height away from game? "

Learner – Assessment

Skill Criteria: -Child not positioned accurately -prompted -once positioned, all fine ? – ✓

~~Strength~~ Force: Asked if result = average height -Confirmed, accurate assess. ? then ✓

Fitness: -Done w/out assistance -Id'd point of fatigue approp. ✓

Motivation: -Asked for ascent ✓

Practice ADAPTION – Structured

Schedule: Teacher not ~~ASKED~~ N/A "I'd have no problem w/ comp assessing child for me "

Variability: N/A Not ~~ASKED~~. " I could do it on my own next time" -but nice having you"

High Effort

Skill Criteria: -Set height to correct position -full jump ✓ -prompted child to -return to ~~starting~~ position.

Fitness: -Set timer fine ✓ "easy" -followed guide closely to do so

Strength: -moderate net height ✓ -intuitive setting

Instruction – Structured

Schedule: -repeat inst. ~~N/A~~ -confident, competent + instinctive -little attention paid to manual

Variability: "have I just adapted a game!" -Direct & demonstration -variety -intentionally

Instruction – Multi Type

Direct Instruction: -Dem of full criteria ✓ ☺ -Asked child to remind her of criteria -fed back exactly ☺

Mastery Motivational: N/A. "I like that I can model!". "I could brainstorm the criteria on a flipchart"

Feedback – Structured

Frequency: -language – more internal not invariant effect. -prompted, then adjusted fine. •HFF ✓ - intuitive process ✓

Focus: -Teacher had to concentrate on language (invariant effect) -not as intuitive

Feedback – Multi Type

Knowledge of Performance: -KoP ✓ -natural + instinctive

Knowledge of Results: -KoR ✓ natural + intuitive

Normative: Norm ✓ provided fine checked manual

" we know our children, their nuances and can respond to them " "big-picture understanding".

" when child struggled to reach yellow line I knew (he was fatigued".

" once you do it once, its simple" "I missed putting him on the right spot @ the start, I'd be fine next time "

" Height lines are v. good, helped me to see when he was tired!!"

" That was really easy, so much easier than I thought it would be "

" very much in the vane of the way we teach"

" I wouldn't normally assess these parameters"

" wouldn't know how to assess these parameters away from game".

FIGURE 5.9 SAMPLE FORM OF TEACHER DEPLOYMENT EXPERIENCE

Teacher experiences with deployment are best discussed in parts, the sum of these parts then reveal the effectiveness of the deployment process as a whole. The first part of deployment involved a Learner Assessment, to be carried out during a 'practice trial'. The experience of teacher #1 with the deployment of this learner assessment process is transcribed below in table 5.4. This transcription also includes additional comments, thoughts and feedback from the other teachers with the same part of the deployment process – Assessment of learner.

TABLE 5.4 TRANSCRIBED TEACHER DEPLOYMENT EXPERIENCE: LEARNER ASSESSMENT

OBSERVATION OF TEACHER EXPERIENCE: TRANSCRIPTION
ADDITIONAL COMMENTS FROM TEACHERS #2, #3 AND #4
GAME: JUMP BALL SKILL: JUMP

	Observation of Teacher #1			
Assessment	**Skill Criteria** -Did not position child accurately at the start. Researcher had to prompt. -Once child was positioned appropriately, teacher accurately and effectively performed baseline assessment of child during an initial gameplay	Strength -Teacher asked if result was based on "average height" of jump. -Once confirmed, teacher accurately assessed the strength of the jump	Fitness -Accurately assessed fitness level without assistance -Identified point of fatigue appropriately	**Motivation** -Correctly asked child for assent
Comments /feedback from teacher #1 (E)	"Useful platform to assess criteria". "I can assess in my room". "I can assess [parameteres] I normally wouldn't e.g. height & fitness".	"How would you even assess the height of a jump away from the game?". "This makes the assessment part so much easier and much more detailed".	"The height helped me to see when the child fatigued" "When the child struggled to reach the yellow line, I knew" "I've never looked at the children's fatigue level in P.E before".	"I don't know how I would do this without the game?".
	• "I'd have no problem with the computer assessing the child for me. I'd trust the results". • "It was nice having you (the researcher) here for my first time but I could do the next one without any help at all". • "I would never have even thought about assessing the strength, fitness, motivation".			
Comments/ feedback from teacher #2 (K)	• "What do I do when he drifts away from the mark?" • "How do I know where to reposition him?". • "Re-aligning could be a tricky process". • "Would it be possible to have a set distance [rubric]? Maybe something like, children who are 3.5m tall, stand 5m away from sensor". • "Or even a mat that is rolled out with the sensor and the child stands at a specific mark on the mat relative to their height". • "It would be great if I could assess two at a time [multiplayer]". • "Assessing in this way [via game play] gives more information". • "A child might have full criteria but poor stamina and be generally unstable; you can see the big picture assessing in this way compared to the TGMD-2". • "I'd feel comfortable assessing even more variables as it was so straight forward". • "Perhaps you could have the net move left and right forcing the child to [perform] the criteria while shifting orientation; this might give even more insight into their ability". • "There could be an additional height line for really exceptional children". • "Overall I'd be happy for the game to do the assessment, once I knew it would be accurate".			
Comments/ feedback from teacher #3 (M)	• "When he drifted [from the mark], I didn't realise it was an issue; I'm not sure I'd know how to judge that on my own". • "I'd love to actually see the assessment done, instead of only reading about how to do it in the manual". • "The child really enjoyed the assessment part, far more than the standard assessment [TGMD-2]". • "Overall I found this part very easy to do, and very informative; it's very indepth stuff". • "If I could be sure the computer was [accurate] I'd be happy for the computer to do the assessment but it's hard to give over ownership of such an important assessment".			
Comments from teacher #4 (S)	• "You could see during the assessment that he couldn't do it; but even by playing the game once you can see he had it." • "You can formally assess and informally assess as they play; it's easy to see improvements." • "Using the game as an assessment really is brilliant, it means I don't have to drag my class outside or to the PE hall". • "I can assess children throughout the day and they actually want to do it". • "Computers are generally more reliable so I'd be happy for the machine to assess the child and give a score." • "Far more in-depth analysis of the skill, things like fatigue and height are so good to know. It gives you a rounded understanding of the child's level".			

Effectiveness of Deployment: Assessment

Overall, each teacher successfully deployed the user assessment. That is, they followed the deployment manual and accurately appraised user criteria, strength, fitness and motivation levels. All four teachers described this part of the deployment process in a positive light, e.g. “easy”, “brilliant”, “in-depth” etc. However, in reality the teachers required assistance from the researcher on several occasions. Further, this assistance was crucial to the accuracy of the assessment results. Thus, without the researcher’s assistance, the learner assessment may not have been accurately deployed. The main difficulty that presented itself during the assessment process was the user’s tendency to stray from the initial starting point. The starting point refers to the specific distance from the sensor typically determined prior to gameplay by the position of the on screen gaming character. For example, if the game character is ‘standing’ on the red line, the user is at the appropriate starting point. However, if the user drifts closer to the sensor, the game character automatically jumps higher. This skews the results of the assessment as a child might be marked capable of a ‘high jump’, when they are more accurately capable of a moderate jump once at the appropriate starting point. The appropriate starting position is illustrated below (fig 5.10).

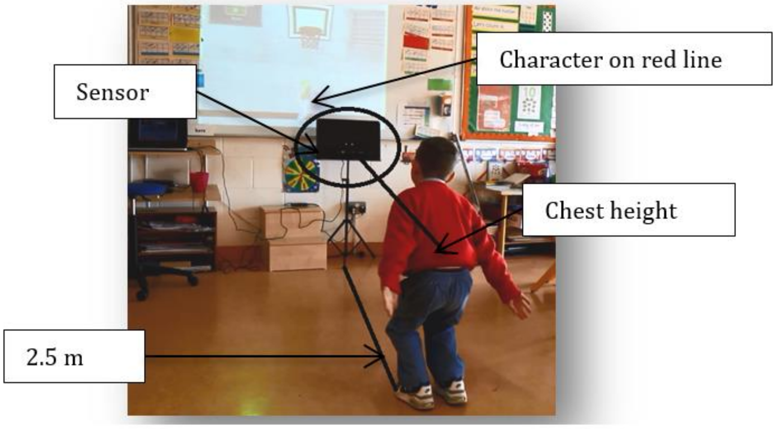


FIGURE 5.10 STARTING POSITION FOR GAMEPLAY AND ASSESSMENT

Ideally, the sensor would accurately detect the user’s starting point and adjust for user drift during gameplay or detect drift and prompt the user to move backwards or forwards accordingly. Teacher #2 made a useful suggestion in line with current technological capabilities by outlining the concept of a ‘roll out mat’ that marks several starting positions directly relating to the child’s height. The idea being that teacher measures the child’s height and matches it to a starting point on the mat therefore providing a consistent starting point. Whilst this is a useful idea, the problem is that the child’s height is not the only factor involved, indeed the height of the sensor is also a significant variable. Additionally, sensor height is adaptable meaning 3D sensors are rarely placed in the same position every time they are used. Therefore, the current format of judging the starting position by the online game character (when character is on the red line, child is at starting point) appears to be the most consistent method and one that worked best for the researcher over the action research period. However, it seems important to emphasise this fact more clearly in the Teacher Deployment and Adaption Manual.

There was also consensus for the fact that teachers would be happy for the computer to fully assess the child, should there be technological improvements and robust evidence to support sensor accuracy. Whilst this is currently not an option, further advances in sensor accuracy are likely pending and an independent 'sensor assessment' may well be a viable option

All teachers expressed surprise and even excitement, at the fact that the assessment process included a measurement of additional variables typically ignored by standard assessment procedures e.g. TGMD-2. Teacher #3 felt that the assessment though gameplay supported a more rounded understanding of the child's motor acquisition. Two teachers referred to the fact that game assessment could be done in the classroom, at different points throughout the day and that the children actually wanted to be assessed in this way. Teacher #3 also asked if there could be a two player option to enable two assessments at the same time. Whilst multi player options were developed for this study, a multiplayer assessment was never deployed or trialled by the researcher, however this concept presents as a potentially time saving process that could be valuable to teachers and the constructs of the classroom and curriculum.

Ultimately a user assessment was successfully deployed by all teachers. The process would benefit further from the inclusion of more explicit detail relating to the starting position of the user in the Teacher Adaption and Deployment Manual. Teachers viewed the additional assessment of the user's fitness, strength and motivation in a positive light and valued the fact that the assessment process could be deployed in the classroom, providing them with more flexibility in terms of their timetable (they could potentially assess in chunks through the day or over the course of a week). Overall, teachers understood that the results of the assessment would be used to inform individualised practice (gameplay) which requires *adaption*. The effectiveness of the adaption process, from the teacher's perspective, is transcribed below (table 5.5) once more with an outline of teacher #1's 'typical' experience and additional comments and insights from teachers 2, 3 and 4.

TABLE 5.5 TRANSCRIBED TEACHER DEPLOYMENT EXPERIENCE: ADAPTION (PRACTICE)

<table>
<tr><td rowspan="2">Adaption
For individualised Practice</td><td>Structured</td><td colspan="3"><u>Schedule & Variability</u>
- Deployment experience was tracked using one child/one skill/one game
- Teacher was not asked to decide on schedule or variability</td></tr>
<tr><td>High Effort</td><td><u>Skill Criteria</u>
-Teacher set net to appropriate height, eliciting a full jump (whole skill) from the user
-Teacher prompted child to return to starting position several times. Thus, ensuring jumps were performed with full criteria during gameplay</td><td><u>Fitness</u>
-Teacher was able to set timer in line with child's point of fatigue (as identified during initial assessment)
-Teacher used manual closely to do this, but did so independently</td><td><u>Strength</u>
-Teacher set net height to 'moderate' (as identified during initial assessment)
-Teacher did this intuitively without paying much attention to the manual.</td></tr>
<tr><td colspan="2">Additional comments from teacher #1 (E)</td><td colspan="3">• "That was really easy, so much easier than I thought it would be".
• "I missed placing him on the right spot at the start, I think I'd do that properly the next time"
• "Once you've done it once, it's very simple".
• "Have I just adapted a video game?".</td></tr>
<tr><td colspan="2">Comments from teacher #2 (K)</td><td colspan="3">• "That [the adaption] wasn't a lot to ask at all; it was totally doable".
• "It was very simple, you adjust the height, change the points and timer then give feedback and instruction".
• "I could adapt more things if needed, even for aesthetic purposes".
• "What could make it even easier; if you could click and drag in 'full screen' and change the timer/score in full screen. Just clicking on the features and typing or dragging".</td></tr>
<tr><td colspan="2">Comments from teacher #3 (M)</td><td colspan="3">• "You think it's going to be more complex than it is; I actually found this easy to do".
• "The next time I do this, it will be very easy".
• "It's very intuitive actually".
• "If you see it in action, it becomes clear that anyone can do it".
• "You can be told something is great but you generally forget about it; whereas if you see it in action it sticks in your brain".
• "These adaption parts were fine and straightforward".
• "I was nervous coming in because I don't have a huge amount of computer experience or with teaching motor skills".
• "I think I could set it all up myself, everybody has projectors etc., it's just plugging in..".</td></tr>
<tr><td colspan="2">Comments from teacher #4 (S)</td><td colspan="3">• "Can you believe it? I could do it and it was actually very easy".
• "The whole process is pretty intuitive, if you see a child can't reach the net, lower it. If the child is tired, cut the time short and if they aren't that great give them a few extra points. Right?".
• "I thought this would be hilariously bad, because I am no 'tekkie' but it was really easy".</td></tr>
</table>

Effectiveness of Deployment: Adaption

All four teachers expressed concern and/or demonstrated low confidence prior to attempting the adaption part of the deployment process. This part was described by one teacher as "tekkie". However, the reality was very different in that teachers found the adaption of game design features "very easy", "intuitive", "fine" and "straightforward". The adaption process was made easy by the choice of development tool – Scratch, which meant that 'adaption' simply involved a veritable click and drag. However, teacher #2 noted that game design features could only be adapted when the game was stopped (typically prior to game play) back in the main *Scratch* interface; suggesting that features be adaptable even during gameplay, on full screen. This would potentially make an already straightforward process an even easier exercise.

Teacher #4 reiterated the process as if to ensure that they had been successful. "If you see a child can't reach the net, lower it. If the child is tired, cut the time short and if they aren't that great give them a few extra points". This summary not only highlighted the teacher's understanding of the adaption process but also spoke to their understanding of the relationship between assessment results and the adaption of game design features. Fundamentally, the researcher always felt confident that teachers would be capable of adaption via Scratch, what was in doubt however, was the teacher's ability to utilise assessment results effectively, adapting game features to suit the individual needs of the user. These doubts were dispelled following the observation period as all teachers demonstrated a clear understanding of the link between assessment results and adaption. No teacher required prompting during this part of deployment. All teachers effectively utilised their results to adapt the paramaters of practice (net height, game legth etc.) to suit the individual needs of the child.

Interestingly, teacher #2 felt capable of adapting other game design features, "even for aesthetic purposes" should it be necessary. Indeed, changing game characters or backgrounds to suit the specific tastes and interests of the users could lead to improved motivation. Further, this type of 'adaption for motivation' *was* briefly considered during the development of video games for locomotor acquisition but ultimately omitted. It was deemed potentially too time consuming to create a bank of characters and backdrops (based on popular television/literary characters) with the ability to appeal to the whole cohort; in addition, it was believed that teachers would not respond well to having too many elements to adapt. A belief that perhaps no longer holds, at least from the point of view of teacher #2.

Whilst the adaption part of the deployment process was met with hesitance, the final two parts of deployment inspired confidence. That is, teachers demonstrate significant experience with the delivery of instruction and feedback. These are areas of deployment they deemed to be "part of their job". The effectiveness with which teachers delivered instruction and feedback can be deciphered from tables 5.6 and 5.7 (below). Both tables present the experience of teacher #1 (typical for all teachers) with additional comments and insights from teachers 2, 3 and 4.

TABLE 5.6 TRANSCRIBED TEACHER DEPLOYMENT EXPERIENCE: INSTRUCTION

<table>
<tr><td rowspan="2">Instruction</td><td>Structure</td><td><i>Schedule</i>
-A schedule was adhered to by the teacher, with the (novice) learner receiving regular instruction
-Teacher instruction was confident, competent and instinctive
-Teacher paid little heed to the manual</td><td><i>Variability</i>
-Teacher varied between direct instruction and demonstration intuitively
- Teacher varied instruction intuitively without paying significant attention to the manual</td></tr>
<tr><td>Multi Type</td><td><i>Direct Instruction</i>
-Teacher accurately demonstrated full criteria for the user
-Teacher asked the child to remind her of the criteria she was looking for. Child fed back the criteria verbatim
-Teacher language naturally focused on “internal features” e.g. “lift your arms” as opposed to movement effect, e.g. “reach higher”
-Once prompted, teacher adjusted their language appropriately</td><td><i>Mastery Motivational</i>
- Deployment experience was tracked using one child/one skill/one game
- Teacher was not asked to foster mastery motivational instruction</td></tr>
<tr><td colspan="2">Additional comments from teacher #1 (E)</td><td colspan="2">• “I like that I can model, the children relate to me and make a real life connection”.
• “I could also elicit from them what they think they are supposed to do by brainstorming the criteria on a flip chart pre-practice”.
• “The script in the manual is helpful to give me an idea, but the instructional approach is very much in the vein of the way we teach, so it’s an intuitive and instinctive process even”.
• “I’d like to think that teachers would always be capable of providing a better instructional support than a computer because we know our children, we know what makes them tick and we can respond to their needs with a ‘big picture’ understanding”.</td></tr>
<tr><td colspan="2">Comments from teacher #2 (K)</td><td colspan="2">• “I like that I give the instruction, it makes me feel more in control”.
• “It’s not just me pressing play, I’m involved”.
• “I know the children in my class, I know their language and they know when I’m sincere; so when I encourage them and praise their efforts it has real weight”.
• “I’d love the computer to give instruction just so that I can be reminded of the types of instruction to give, it would prompt me to build on that instruction”.
• “I think it’s always going to be better to receive instruction from a human as opposed to a computer”.</td></tr>
<tr><td colspan="2">Comments from teacher #3 (M)</td><td colspan="2">• “I think I can demonstrate the skill far better than the computer could; I can adjust my language, speak enthusiastically and use the relationship I have with the children in my class to promote confidence and effort”.
• “It would be great for the computer to give instructions in the right way, then I could build on them instructions, so we’d be working together so to speak”.</td></tr>
<tr><td colspan="2">Comments from teacher #4 (S)</td><td colspan="2">• “I liked being able to model the skill. You could see him really watching me and then doing a much better jump when he tried the second time”.
• “It’s good that the teacher gives the instruction, because the child knows that if I reinforce them, I mean it”.
• “I think since you’re their teacher you can really motivate them more than a computer and get a really good effort out of them”.</td></tr>
</table>

TABLE 5.7 TRANSCRIBED TEACHER DEPLOYMENT EXPERIENCES: FEEDBACK

<table>
<tr>
<td rowspan="2">Feedback</td>
<td>Structured</td>
<td colspan="3"><u>Frequency</u>
-Frequency of feedback was in line with user needs
-Intuitive process for the teacher who based the timing on instinct and experience.</td>
<td colspan="3"><u>Focus</u>
-Teacher really had to concentrate to focus on movement effect.
-Not as intuitive but negotiated successfully by the teacher</td>
</tr>
<tr>
<td>Multi Type</td>
<td colspan="2"><u>Knowledge of Performance</u>
-Provided KOP
-Natural and instinctive delivery</td>
<td colspan="2"><u>Knowledge of Results</u>
-Provided KOR
- Natural and instinctive delivery</td>
<td colspan="2"><u>Normative</u>
-Provided Normative Feedback
-Checked manual in order to remember this third feedback parameter. Thus, not as instinctual</td>
</tr>
<tr>
<td colspan="2">Additional comments from teacher #1
(E)</td>
<td colspan="6">• “I think as teachers we understand instruction and feedback instinctively, I didn’t feel the need to have to refer to the manual here, and yet I think I provided the appropriate types”.
• “However, I’m not sure I would have paid much attention to normative feedback, or false positives without the notes in the manual”.
• “The scoring system and the fact that I can differentiate the game very subtly makes that normative aspect really promising”.
• “Because I have a relationship with the user, I think my feedback carries more meaning.”
• “I think I’d always like to be involved in that aspect”.</td>
</tr>
<tr>
<td colspan="2">Comments from teacher #2
(K)</td>
<td colspan="6">• “Computer feedback could remind the teacher of the types of feedback we could give and I could elaborate and cater it for the child”.
• “I think the feedback I gave was more natural; it’s a huge part of my job as a teacher”.
• “I like that I’m involved in the game”.
• “Scripting the instruction and feedback in the manual is such a great idea to prepare the teacher”.
• “We can then bring the script to life, you know teachers, they’re great actors”.</td>
</tr>
<tr>
<td colspan="2">Comments from teacher #3
(M)</td>
<td colspan="6">• “Giving feedback and instruction with an external focus is a bit tricky; I had to keep reminding myself”.
• “I like that there is essentially a script to help me structure my feedback”.
• “I prepared the vocabulary before I started the game”.
• “Wouldn’t it be cool if the game provided feedback and used vocabulary that then prompted the teacher on the type of things to say; like a script prompter”.</td>
</tr>
<tr>
<td colspan="2">Comments from teacher #4
(S)</td>
<td colspan="6">• “I forgot a few times about the external feedback [movement effect]”.
• “I kept mentioning his arms – lift your arms, put your arms behind”.
• “I’d like the computer to remind me of the lingo [for the external focus] so I’m not always saying put your arms behind etc.”.
• “All in all it’s a fairly natural balance between the instruction and feedback; it’s something, as teachers, we are very comfortable with in general”.
• “You could see him really take on board the feedback and fix the way he jumped. It’s really great actually to see the immediate improvement in technique”.
• “To be able to establish the flaws and get the child to jump the right way that quickly is super”.
• “I don’t think anyone gives better feedbck than a teacher, it’s such an important part of our job, to know the child your dealing with and to adjust your feedback to meet their sensitivities”.
• “I think it’s great that it’s a real collaboration between the teacher and the game; you’re not just pressing play and leaving the child to it. You’re involved. You’re important”.</td>
</tr>
</table>

Effectiveness of Deployment: Instruction and Feedback

The provision of instruction and feedback by all four teachers proved particularly effective. The confidence with which teachers delivered both principles was notable, likely owing to the fact it is such a large “part of [their] job”. Indeed, “as teachers [they] understand the importance of feedback and instruction”. In general, teachers described this part of the deployment process as “intuitive”, “instinctive” and “natural”. Teacher #2 stated that the instructional approach outlined in the manual was “very much in the vein of the way we teach”. This was apparent in the way all four teachers delivered concurrent instruction, rarely referring to the manual or looking to the researcher for support/advice. Teachers were particularly successful when it came to providing demonstration. For example, teacher #2 noted that the child related to them and could therefore make real life connections. This was corroborated by teacher #4 who stated that “you could see [the child] really watching [the teacher] and taking it in”. Teacher #2 also suggested brainstorming with the children, eliciting the criteria they are expected to perform, then recording the criteria on a flip chart prior to performance. This presents as a positive suggestion to reinforce the child’s understanding of what is being asked of them, it also represents a form of cognitive rehearsal or mental practice (advocated by several authors and outlined in state of the art section 2.6). Teacher #3 expressed that the provision of instruction puts the teacher in a position of “control”, whilst teacher #4 proudly added that it meant their role in terms of game deployment was not just, “teacher presses play”.

Similarly, the provision of feedback was also observed to be a confident and intuitive process. However, teachers noted that the language used for ‘movement effect’ required concentration. Essentially, teachers were encouraged to focus on the effect of the movement (“get the ball higher”) and not the movement itself (“lift your arms higher”) when providing feedback/instruction. This was described as “tricky” by teacher #3, supported by teacher #2 who laughed, “I kept mentioning the arms – lift your arms, put your arms behind you”. Ultimately, all teachers required minimal prompting relating to the focus of their feedback. Once reminded, teachers presented as capable and competent in providing feedback with movement effect. This “tricky” component of feedback and instruction inspired some innovative suggestions from the teachers. For example, teacher #2 proposed that the computer could provide feedback as onscreen text reminding the teacher of the appropriate language. Theoretically, the teacher could then bring this instruction to life using a pre-existing relationship with the child to ensure that feedback and instruction were deployed effectively.

Indeed, the importance of the teacher’s relationship with the user (their student) relative to the computer’s (non-existent) relationship with the user was stressed several times over the research period. Teachers felt that this was a particular strength from an instructional/feedback point of view. Teacher #4 summed it up as, “I don’t think anyone gives better feedbck than a teacher, it’s such an important part of our job, to know the child your dealing with and to adjust your feedback to meet their sensitivities”. This ‘adjustment to sensitivities’ was noted throughout the research period particularly in the way teachers spoke to their users. For example, teacher #1 was animated and loud when delivering instruction/feedback to their user whilst teacher #3 was more soft spoken and calm. Interestingly, the tone of their voices was in line with the personality of the user. Teacher #1 had adjusted for a confident and competitive child, whilst teacher #3 observed that their child was shy/introverted and adjusted accordingly. It's difficult to imagine that these "sensitivities" could ever trully be detected by a computer, which means that even if sensor accuracy dramatically improves, there will always be a need to involve the teacher in the deployment of video games for locomotor acquisition, to provide fully effective feedback and instruction specifically catered to the user (student). In turn, teacher #2 felt that because of an existing relationship, feedback from the teacher carried "real weight". This would suggest that reinforcement/feedback from a teacher could enhance the motivation of the user more effectively than reinfrcement from a computer. It is also interesting to note teacher #2's comments about "speaking the user's language", essentially replacing general 'Americanisms' often associated with gaming e.g. "awesome" and "great job"; with more familiar terms the child hears throughout the school day, across the curriculum. Thus, when evaluating the teacher's delivery of instruction and feedback, it has to be stated that teachers not only prove effective, but potentially more effective than a computer could ever be.

Effectiveness of Teacher Deployment: Overall Process

With that, the deployment of video games for locomotor acquisition can be described as an effective process from two stand points. First, teachers were capable of doing all of the things expected of them in the teacher adaption and deployment guide. This included an assessment of user, adaption of game features to suit individual needs and the delivery of appropriate feedback/instruction. Whilst some aspects of deployment were more intuitive than others, overall teachers described the process as "straight-forward" and even "easy". Additionally, teachers intuitively did a number of things not asked of them in the manual to enhance the deployment and overall gaming experience. For example, a pre-existing relationship between teacher and user meant that the nuances and sensitivities of the user were catered for during gameplay; as exemplified through the soft and calm tone of voice adopted for an introverted user compared to an animated and excited tone of voice adopted for an extroverted user.

Thus, prior to the research period the teacher was considered a *necessary* component of the adaptive process, because of 3D sensor technical limitations. However, the results in this study suggest that the teacher is not merely a replacement for inaccurate technologies, but rather an intelligent system that, by understanding nuances of the user, enhances the effectiveness that gameplay has on the user. With that, the final evaluation is concerned with user outcomes. Essentially, do video games for locomotor acquisition work; do they lead to improved locomotor acquisition? The results of an evaluation into user outcomes is presented below.

5.4.3 RESULTS OF EVALUATION 3: EFFECTIVENESS OF VIDEO GAMES FOR LOCOMOTOR ACQUISITION

The action research applied in this thesis included an eight-week period of video gameplay in the classroom. 48 children participated in video games for locomotor acquisition on a daily basis. Results from a pretest on locomotor acquisition using TGMD-2 (Ulrich, 2000) established that the cohort demonstrated poorly developed locomotor skills at the beginning of this study (table 5.8). Mean scores for each locomotor skill were classified in the "at risk" category (Ulrich, 2000)

TABLE 5.8 PRETEST: RAW SCORES FOR EACH LOCOMOTOR SKILL

Variable	**Mean**	SD	**Highest Potential Score** Out of a possible:
Run	4.2	1.6	8
Hop	2.2	1.7	10
Jump	4.1	2.9	8
Skip	1.9	3.7	6
Slide	2.1	1.9	8
Total Locomotor	**14.5**		40

The effects of daily participation in video games for locomotor acquisition were revealed as significant even by the half way point (interim test). That is, mean scores of each locomotor skill had improved by a statistically significant margin at week four. The cohort also made further significant improvements in overall locomotor performance from interim to posttest. Interim and posttest results were as follows:

TABLE 5.9 TOTAL RAW SCORE FOR LOCOMOTOR SKILLS AT INTERIM AND POSTTEST

Variable	**Interim Mean**	**SD**	**Posttest Mean**	**SD**	**Highest Potential Score** Out of a possible
Run	6.3	2.1	6.9	2.4	**8**
Hop	6.5	1.7	7.9	2.8	**10**
Jump	6.8	2.2	7.1	2.3	**8**
Skip	2.7	4.2	3.4	4.8	**6**
Slide	5.2	2.4	6.3	2.8	**8**
Total Locomotor	**27.5**		**31.6**		**40**

It should be noted, that the posttest was conducted 2 weeks after the final practice session (gameplay). This was done to account in some fashion for retention. Indeed, studies on motor acquisition have revealed a litany of counter-intuitive findings (Lee & Schmidt, 2008). That is, improvements are often identified during practice but not away from the training program during a retention test. However, in this study users demonstrated improved performances 2 weeks after final practice. Indeed, mean scores, following the research period, moved the cohort from the 'at risk' category to a score that could be described as 'well developed'.

However, there was also a pronounced variance in the scores of specific locomotor skills signifying that improvements were experienced by most children but not all. This variance is particularly noticeable in the locomotor skill of 'skipping'. Indeed, the researcher (in role as teacher) also observed a notable difference in children's ability to skip whilst playing the video game, 'Skip Attack'. Conversely, this game was developed to target 'skipping' but was not able to elicit typical skip criteria because a forward skip was not logistically possible in the classroom. Instead, users were asked to 'side skip' left and right. These outputs required the same rhythm and similar pattern to a forward skip. Since Sidaway et al., (2012) states that practising a motor pattern similar to or near to a desired skill may be effectively transferred owing to 'generalization', it was hoped that accurate side skipping could potentially lead to accurate forward skipping. It appears that a large proportion of the cohort were able to transfer this skill, but not all. Further, since a *side skip* pattern also relates to the *slide* pattern, it could be stated that the improvements made sliding (posttest results were almost as high as the basic skill, run) are attributed to the fact that the skill was, in some way, practised in two different games. Overall, mean locomotor acquisition scores for each skill improved by statistically significant margins (P<0.05 was considered significant) but moved to, or beyond, standardised aged based scores from pretest to posttest, across all skills. The group demonstrated an overall locomotor improvement of 17.1 marks (below, table 5.10).

TABLE 5.10 COMPARISON BETWEEN PRETEST AND POSTTEST

	Mean	Maximum potential score
Pretest	14.5	40
Posttest	31.6	40
Difference	***17.1***	

The real question is, what exact factor(s) lead to the observed gains in locomotor performance by the users? Let us first take **time** (i.e. 8 weeks of focused locomotor training) into account. Essentially, we know that motor training programs typically run for a similar period (6-8 weeks) (e.g. Connor-Kuntz & Dummer, 1996). However, most of these programs lack hard evidence to support their worth (Gallahue et al., 2012) and even more concerning, those that do, are potentially not all they seem. In a study by Connor-Kuntz and Dummer (1996), the authors found *significant* gains in locomotor skill performance as a result of the (8 week) intervention, yet despite these improvements, the cohort still performed below expected standard scores for their age at posttest. This implies that the average child demonstrates such poor locomotor performance that they can experience statistically significant gains and still remain in an 'at risk' category (TGMD-2, Ulrich, 2000). Therefore, whilst an extended period (e.g. 8 weeks) of focused locomotor training is likely to bring about improvements, it is unlikely to facilitate high level gains that constitute 'well-developed' locomotor skills. Interestingly, a similar pattern of improvement was observed in this thesis. That is, users improved by significant margins at the halfway point (interim test), but these improvements did not suggest well-developed locomotor skills. The rate of improvement from interim test to posttest proved smaller but also crucial, as ultimately, higher levels of locomotor performance (well-developed) *were* observed at the end of the study.

Could these additional improvements be attributed to the task, i.e. **video gameplay**? After all, Gallahue et al., (2012) state that motor learning develops at rapid rate when a training task fits in with learner interests. Having previously examined the affects that an extended period of *commercial* video gameplay had on user locomotor skills (McGann & Arnedillo-Sánchez, 2014), this would appear not to be the case. Essentially, commercial video games (that elicit locomotor outputs from the user, also outlined in table 2.3, in this thesis) do not support significant locomotor improvements owing to a lack of purposeful design (McGann & Arnedillo-Sánchez, 2014). This means that, independently, time and video gameplay are not necessarily conducive to high levels of improved locomotor performance. Ergo, the success of the intervention in this thesis, is more likely to be a result of **PaCMAn**, the theoretically informed framework that underpinned game design, development and deployment. PaCMAn was delivered through **gameplay**, with user performance improving over an extended period of **time**. Thus, a dynamic interaction between these factors (time, video games, and PaCMAn) was effectively 'at play'.

At this point, it should be stated that PaCMAn is difficult to support in real life situations. First, parts of a learner assessment, particularly in relation to identifying a user's force and fitness level, are 'easier' (i.e. faster, more accurate, more logistical) to assess within a gaming environment (McGann et al., 2016). The users are motivated by the constructs of gameplay and nonparticipants present as happy to watch on. Consider measuring the average height of a student's jump, or average point of fatigue away from video games, in the school gymnasium. Logistically, teachers have to assess one student at a time whilst the rest of the class watch on. Nonparticipants become bored, whilst participants are unlikely to exert maximum effort (McGann et al., 2016). In terms of enjoyment and compliance, research has also previously shown that video games (used to support improved balance in children) are more enjoyable and less difficult than real life (balance) exercises (Vernadakis et al., 2014).

A PaCMAn video gaming experience also manages to bring locomotor training and acquisition into the classroom. This means the teacher is not dependent on the weather (for outside practice) or the availability of shared spaces (e.g. gymnasium). Ultimately, adaptable video games for locomotor acquisition, underpinned by a principled 'PaCMAn' framework and deployed in a manner outlined by the Teacher Adaption and Deployment Guide, are empirically supported by this study as an *effective* tool to support the training of well-developed locomotor skills in the classroom setting.

Several elements of these adaptable video games were observed (by the researcher) as being particularly unique and effective. First, they provided users with opportunities to observe successful others (normative feedback). This was facilitated through a multiplayer option meaning users could learn from one another during gameplay/practice. In addition, children in the class were often keen to observe skilful peers in order to emulate their success. Observation of their peers was made easy by virtue of the fact that gameplay took place in the middle of the classroom, projected on to a whiteboard that children are almost conditioned to pay attention to during class time. This meant that nonparticipating were keen to observe successful others. A similar interest from nonparticipating student's is difficult to elicit in real life situations.

Second, because of the nature of the environment (classroom), users had an audience during gameplay which potentially *motivated* them to perform with additional effort in order to appear successful and competent. In terms of motivation, children in this study were generally motivated by success. This 'success' was largely determined by the score at the end of play. Indeed, deployment forms gathered during the research period highlight a litany of questions from users relating to their score, i.e. users wanted to know how their score compared to their peers; and also how it compared to their own previous attempts. This type of *intrinsic* motivation where learners want to perform to *their* own potential, is fostered in the primary classroom particularly at infant level, across all subjects. This means that users may approach gameplay in the classroom differently to how they would approach it in the home.

Even still, achieving a 'bad' score can be damaging. We know that in real life situations, children typically avoid participating in activities they don't feel competent in; furthermore, competency is typically identified by comparing one's own performance against that of a peers. Whilst it is generally difficult to disguise learner differences and differentiate real life physical activities, gameplay offers more flexibility. For instance, in this study, *false positives* (Wulf, 2010) were delivered to users identified as unlikely to achieve the same results as their peers. For example, children who lacked fitness and force were awarded two points every time they scored, as opposed to the one point for more successful children. The rate (speed) of a ball, and height of a net was also decreased to support subtle differentiation. This meant that no learner scored significantly lower than their peers, potentially facilitating continued efforts and motivation. Ultimately, the most capable children achieved the highest points but the gap between strong and weak performers was perceived (by the weak children) to be far less than it actually was.

This brings us to the third unique element of gameplay, which relates to the accuracy of user outputs. Unlike commercial video games, the outputs performed by users in this study were rarely cheated. On the contrary, it became clear to the cohort that accurate skill criteria lead to an economy of motion, faster skill performance and consequently, more points/more success. This economy of motion was developed further as the children strived for better scores. The highest scores came from children particularly adept at *joining* skills. This skill joining process became increasingly more economical over the course of the research. Figure 5.11 shows a user demonstrating an apparent pause in between two accurate jumps (returns to an upright position after first jump). Compare this to another user who joined both jumps together seamlessly (lands in bent knee position ready to jump again). Whilst both users would score full criteria using the TGMD-2 (Ulrich, 2000), the second user demonstrates more automaticity of movement and a higher level of fitness. This second child was the most successful in the class, received the highest score and maintained fitness for the longest period of time. The economy of motion adopted by this learner was fostered by the objectives of the game which provided an impetus not only to perform accurate criteria but to push a step further and link skills in the most economical way possible.

- USER LANDS IN UPRIGHT POSITION (STILL PHOTO NO. 3)
- THIS ACTS AS A FULL STOP BETWEEN EACH JUMP
- STIFLES SPEED OF CONSECUTIVE JUMPS

- USER LANDS WITH KNEES BENT (STILL PHOTO NO. 3)
- THIS CONNECTS ONE JUMP TO ANOTHER
- MAXIMISES SPEED OF CONSECUTIVE JUMPS

FIGURE 5.11 MODEL FOR SUCCESS – LINKING ONE JUMP TO ANOTHER

Interestingly, successful children were observed closely by their peers in an attempt to emulate their results. Deployment forms (appendix 4) underline this point with apparent dialogue between nonparticipating users, e.g. "How does he go so fast?", followed by "he's landing down low on the ground". Children were able to identify the appropriate model (child 2) and decipher what made the performance so effective. Whilst the linking of skills is not measured by standardised gross motor assessment kits (e.g. TGMD-2), it proves to be a useful measurement that allows teachers (and peers) to distinguish between good and excellent. Furthermore, an automaticity of movement could potentially transfer to more complex play. Which is, after all, one of the ultimate goals of locomotor skill acquisition.

5.5 SUMMARY

Overall, video games for locomotor acquisition can be described as an effective platform to support improved locomotor performance. This effectiveness is dependent on PaCMAn, video games and time. PaCMAn, a theoretically informed framework, is used to underpin game design, development and deployment. Without this framework, video gameplay and an extended period of practice, typically fail to support high levels of locomotor skill acquisition. However, with PaCMAn, the opposite is true. Principles and conditions of motor acquisitions are delivered through an adaptive deployment process between teacher and game. This is outlined by a Teacher Adaption and Deployment guide, which can also be deemed relatively effective. That said, several factors require further consideration or *scaffolding*, particularly in order to ensure that the teachers (the human adaptive component) do not become frustrated with the process.

Ultimately, with technological advances, such as improved 3D sensor accuracy, the deployment process may change but the real success of the PaCMAn framework is that it presents as *agnostic* and potentially delivered in a variety of ways. Another significant finding is that teachers demonstrate an understanding of individual user sensitivities. Thus, future versions of 'Locogames' should continue to retain the adaptive process between game and teacher, empowering the teacher to remain a significant part of deployment and ensuring that PaCMAn is delivered, in full. The following chapter concludes this thesis by comparing results ascertained with findings already established in the literature. This comparison will highlight the main contributions of this paper. The conclusion will also be used a platform to outline future work and the future of video games for locomotor acquisition in the classroom.

6 CONCLUSION

This chapter examines the extent to which this thesis met the research objectives laid out in chapter 1. It includes a specific outline of the contributions made and discusses future work that could be conducted to potentially extend/enhance the research further. The chapter (and thesis) concludes with a discussion on the future of video games for locomotor acquisition and includes a design blueprint, informed by data collected over the course of this research, that could transform a perceived barrier of locomotor acquisition (video gameplay) into a popular and effective training ground.

6.1 OBJECTIVES AND CONTRIBUTIONS

The research question that this thesis set out to examine was *how can video games for locomotor acquisition be designed for effective deployment in the classroom?* The question was sub divided and tackled in parts concerning the (i) design (ii) deployment and (iii) effectiveness. This meant that there were essentially three objectives stemming from the research question, outlined in chapter 1.

1. The first objective (concerned with design) was to iterate a theoretical and principled design framework (PaCMAn) that could be utilised to underpin development of video games for locomotor acquisition.
2. The second objective (concerned with deployment) was to analyse how this framework could be delivered through video gameplay in the classroom and outline the overall deployment process.
3. The third objective (concerned with effectiveness) was to conduct an evaluation into the effectiveness of these video games, first from the perspective of the teacher i.e. were they capable of deployment; then from the perspective of the learner i.e. did gameplay facilitate improved locomotor skills?

The following sections will examine the extent to which the thesis met these research objectives.

6.2 DESIGN: THE CONSTRUCTION OF A PRINCIPLED DESIGN FRAMEWORK

Research objective one was *inspired* by the following points identified through a state of the art review:

- Video games revealed to be a popular but sedentary pastime that potentially block locomotor acquisition in modern day children
- A new genre of exergames with 3D sensor control systems facilitate gross motor interactivity
- Several exergames identified as eliciting locomotor outputs from the user but designed for recreational purposes or to improve fitness
- No purpose built video game for locomotor acquisition could be identified
- Non-virtual training programs revealed to be largely ineffective owing to a lack of principled design
- Purpose built video games for locomotor acquisition would require an underpinning principled design framework
- No such framework could be identified in the literature

Ergo, research objective one, the formation of a principled design framework to support locomotor acquisition, was initially tackled through an analysis of the literature on gross motor training and acquisition, concluding the state of the art. This analysis took an *inductive approach* that involved:

- A systematic investigation into literature on gross motor acquisition and training that (i) referenced motor learning theory, principles, conditions or rules (ii) provided empirical evidence to support improved performance
- The collation and compilation of all principles and conditions referenced (or inferred) by these papers
- An initial sorting process that filed principles and conditions into categories relating to learner, practice, feedback and instruction (Dynamic Systems Theory & contemporary theory)
- Identification of principles and conditions most commonly referred to across the literature

Chapter 3, Design, built upon this analysis by:

- Taking the data gathered (list of identified principles and conditions)
- Conducting further analysis to identify patterns (overlapping principles/conditions, interrelated principles/conditions) and principles that prove to be highly effective

- Clustering related principles and conditions
- Identifying parameters related to the learner that could support the decision making process around which combination of principles/conditions best support individual learner needs
- Developing a generalised framework
- Presenting and illustrating PaCMAn
- Providing a sample delivery of this framework (general and explicit)

Theoretically, PaCMAn can be facilitated through play or activities within physical education (P.E). However, several parts (or principles) present as difficult to meet in real life situations e.g. assessment of performance 'product', adaption of practice parameters to suit individual needs, and maintenance of learner motivation levels. These PaCMAn are potentially best supported in a virtual environment. Conversely, the inaccuracy of affordable 3D sensors, as identified through analysis of the state of the art, present as a significant barrier. Thus, if the first objective was to develop a principled framework that could be used to underpin the design of video games for locomotor acquisition; the second objective was concerned with how to deliver this design framework in a gaming environment.

6.3 DELIVERING PACMAN THROUGH VIDEO GAMEPLAY IN THE CLASSROOM

Chapter 4 of this thesis was concerned with the development of video games for locomotor acquisition and their deployment in a classroom setting. This development was centred on the delivery of a PaCMAn design framework in a video gaming environment. The chapter began by conducting an analysis into exergames (outlined in the state of the art review) that call upon users to perform locomotor outputs. The analysis revealed:

- Several parts of the framework are potentially supported through adaption of game design features (e.g. timers, targets, scoring systems and graphic models) that could be altered to meet individual user needs
- Design features and the principles/conditions they correlate with were outlined and illustrated
- Several parts of the framework were identified as 'virtually' impossible to support
- These parts are blocked by technical limitations (3D sensor inaccuracies) and a lack of purposeful design

To negotiate current limitations, the game design process borrowed from recent studies on the use of exergames to support basic gross motor rehabilitation, physical fitness, balance and object control skills (outlined in the state of the art review, section 2.3). These studies identified several key points:

- The clinician/instructor/teacher plays a key role in terms of deployment
- The human's expertise is potentially utilised to overcome any design or technical limitations
- Human chooses a game that could cater to user needs, demonstrates the motor output, adjusts the length of play (or terminates game play) in line with user fitness levels
- The role of the clinician/instructor in these instances could tentatively be described as a 'human adaptive component', adapting characteristics of the game (length of play etc.) based on their expert opinion of user needs and by providing additional instruction that the game does not
- A human adaptive component could potentially support parts of the PaCMAn framework the video game cannot

Video games outlined in this thesis were intended for use in the classroom thus, *the teacher* instantly emerged as a potentially viable 'human adaptive component' with the capacity to facilitate parts of PaCMAn that the game could not. To re-iterate, game parameters for rehabilitation purposes were adapted by clinicians mainly by adjusting *hardware* i.e. power off (to end play at patient's point of fatigue) and sensor re-positioning (to modify the required user output). However, purpose built video games for locomotor acquisition, intended to allow access to design features, making games (and their features/parameters) adaptable. From a locomotor training and acquisition standpoint, exergames currently on the market are typically 'locked in', and rarely adaptable.

This prompted the penultimate stage of development which included:

- Analysis of popular exergames on the market against PaCMAn framework
- Identification of design features that potentially correlate with PaCMAn
- Identification of a suitable authoring tool that facilitates instant adaption of game design features, game control through affordable 3D sensor technology, and appeals to teachers
- Development of design features found to correlate with PaCMAn in this authoring tool (Scratch with Kinect2Scratch)
- Development of four specific games intended to target four specific locomotor skills
- Hypothetical outline of the adaptive process that could potentially be deployed to deliver PaCMAN through video gameplay in the classroom

Ultimately, the delivery of PaCMAn and the overall deployment process of video games for locomotor acquisition in the classroom required a *definitive* outline. This was ascertained by applying action research in the classroom (chapter 5). The researcher, in role as class teacher, tracked and recorded the delivery of PaCMAn through video game play in the classroom (initially with four users and then with two whole classes, n=48). The overall deployment process, delivery of PaCMAn, set up and logistical considerations etc. were consistently recorded using 'deployment forms'. These forms were then analysed to articulate a Teacher Adaption and Deployment Guide.

Once this guide was in place, the deployment process could be evaluated further. In short, the state of the art revealed that video games were rarely used in the classroom because teachers find them technically difficult to deploy and logistically difficult to integrate. Studies on the use of exergames for rehabilitation or gross motor training purposes found that clinicians and teachers required assistance with the deployment process (Levac et al., 2014; Vernadakis et al., 2015). Accordingly, in order for video games for locomotor acquisition to be effectively and consistently deployed in the classroom, teachers would have to be sufficiently supported with the overall deployment process and react positively to the experience. This instigated a final objective of the thesis concerning evaluation.

6.4 EFFECTIVENESS OF TEACHER DEPLOYMENT PROCESS

In recent years, game designers have borrowed from research in an attempt to develop games that can be described as effective teaching and learning tools. This has resulted in a number of *research to practice* hubs featuring collaborations between game developers and researchers. However, there is still a significant lack of consideration for the practitioner (teacher) as well as the constructs of the classroom (Chmiel & Mazur, 2012; Herro, 2016). Accordingly, in this thesis, the role of the teacher is not only considered but incorporated into the design. The teacher is considered a powerful component of deployment. Qualitative data that spoke to the attitudes and experiences of teachers during the deployment process was collected. Four teachers were observed deploying video games for locomotor acquisition in their classroom. They were provided with a 'Teacher Adaption and Deployment Guide' and the Locogame, 'Jump Ball'. Their experience with deployment was assessed in parts relating to (i) assessment, (ii) adaption, (iii) instruction and (iv) feedback. Data collected during the observation of teacher deployment experiences revealed teacher attitudes towards video games for use in the classroom. It also revealed the realistic capabilities of these teachers, to do what was asked of them (i.e. adaption, provision of feedback, instruction, assessment of user etc.).

Findings included:

- Assessment process presented as difficult to begin with; all teachers looked to the researcher for reassurance (table 5.6).
- Typically, assessment (like TGMD-2) is outlined by a full manual; here assessment was reduced to one page in the Teacher Adaption and Deployment Guide
- Teachers ultimately proved capable with one teacher stating that she'd feel comfortable assessing even more variables (table 5.6).
- All teachers rated assessment on the whole as "easy", "straightforward" and even "simple"
- It is important to note that without the basic prompts given by the researcher some of these teachers may have experienced frustration and their overall rating of the process may have been very different
- Teachers guide would benefit from including more detail relating to the assessment process to 'scaffold' the process further

The assessment process proved to be the part of deployment that required the most assistance, however, it was arguably the part of the video gaming experience that impressed the teachers most. For example, teachers deemed several aspects of assessment in a video game environment to be effective and "great". Some teachers felt that the opportunity to ascertain parameters relating to the user's strength and fitness level was novel and valuable. It meant that they could "see a bigger picture" (table 5.5) compared to results typically ascertained through the use of popular gross motor assessment tool kits, including TGMD-2 (Ulrich, 2000).

In this study, user assessment takes place during video gameplay to provide the human adaptive component (teacher) with immediate information. This information is utilised to inform adaption, feedback and instruction. Thus, effective deployment is dependent on effective assessment and further, on the teacher's ability to interpret results and adapt game parameters appropriately. The 'adaption' part of the deployment process was predicted to be the most challenging. However, results proved otherwise:

- Teachers described the process as "really easy" and "intuitive"
- All teachers were observed to utilise results of the user assessment appropriately
- From a technical standpoint, teachers were able to do all of the things expected of them i.e. set timer, adapt scoring system, adjust net height etc.

The remaining parts of PaCMAn to be delivered (feedback and instruction) were effectively deployed from the outset. Indeed, teachers immediately responded well to this part of the deployment process and deemed both instruction and feedback to be “part of their job”. Each principle was effectively delivered by:

- Understanding the nuances of the user
- Adjusting tone of voice to suit user personality
- Adjusting language to suit user vernacular
- Utilising an already existing relationship between user and teacher which meant feedback was positively received
- Delivering scripted/unscripted feedback and instruction outlined in the guide

Overall, the teachers responded positively to the deployment process and were observed as capable of doing everything asked of them in the guide. Several parts of deployment required scaffolding from the researcher, e.g. when users were not positioned accurately at the start of the game, the researcher prompted the teacher to reposition the child. However, on these occasions it was noted that the information required was not featured in the deployment guide and once the teacher was given minimal direction they proved capable of the process. Teachers spoke enthusiastically about the assessment of locomotor skills through video gameplay and about the assessment rubric outlined in the Teacher Adaption and Deployment Guide. It could be stated that this assessment rubric will hold for more sophisticated versions of video games for locomotor acquisition in the future. The same could also be said for the concept of an overall deployment guide. That is, if game designers are to consider the use of a ‘human adaptive component’ (teacher) then an outline of what the teacher is expected to do should also be part of the game development process. Further, the literature outlines resistance to the use of video games in the classroom owing to teacher perceptions that they are too difficult to deploy (Fishman et al., 2014). Accordingly, these negative perceptions should be addressed and tackled. Supporting the deployment process with an easy to follow guide could facilitate a change in teacher perceptions. This change is necessary to take video games for learning to another level. That is, teachers are not merely required to negotiate technical limitations, but to bring an additional level of expertise and experience that a gaming system is unlikely to ever match. As technology changes and games become ‘technically’ capable of delivering PaCMAn without a human adaptive component, one has to wonder if the outcomes of user performance could match those achieved when the game and the human work together. This powerful and dynamic delivery potentially enhances a motor training and acquisition experience, supporting individual needs that otherwise, would go unsupported.

Ultimately, the best way to highlight the effectiveness of this delivery is to show that adaptable games and the deployment process works. Not only from the teacher's perspective, but from the user's. Accordingly, the effect that video games for locomotor acquisition had on user performance was also evaluated in this study with promising results.

6.5 EFFECTS OF VIDEO GAMEPLAY ON USER LOCOMOTOR SKILLS

Video gameplay is often still cited as a sedentary 'finger tapping' pastime that stifles motor acquisition and fosters obesity. However, adaptable video games for locomotor acquisition developed for the purpose of this study, aimed to transform a sedentary activity into a gross motor training platform. The first objectives of the research were concerned with the design, development and deployment of these games in the classroom. Teachers were observed to be capable of the deployment process and spoke positively about the use of video games in the classroom for locomotor acquisition. A final question remained. Essentially, do they work? Can video games for locomotor acquisition facilitate improved locomotor skills?

From this perspective, results were largely conclusive. The cohort demonstrated significant improvements in locomotor performance from pretest to posttest. This improvement was attributed to video gameplay, underpinned by a PaCMAn framework, over an eight-week period i.e. time, gameplay and a theoretical framework. Interestingly, these games did not only foster accurate criteria but also, a high level pattern which saw several users connect skills in an economical fashion. In addition, gameplay facilitated improved fitness level which was evident through user deployment forms (appendix 5). This suggests that gameplay not only supports the acquisition of appropriate locomotor criteria and skills but prepares the user for more complex play by facilitating additional outcomes (including increased fitness, economy of motion and capacity to link skills) that are potentially transferred from video game to real world sports.

The significant impact that video gameplay had on user performance was most likely a result of the theoretically informed framework, PaCMAn, that underpinned game design. We know that other commercial video games (which elicit locomotor outputs from the user) have previously failed to support significant locomotor gains (McGann & Arnedillo-Sánchez, 2014). We also know that an extended period of time practising locomotor skills through real world play has also failed to support long lasting locomotor skill improvements. Thus, the dynamic interaction between games, time and the additional element of a theoretical framework, is likely to be responsible for the improvements made by the cohort in the study. Additional by-products of a gaming environment were particularly helpful. First, video gameplay facilitated a relatively straight-forward approach to *differentiation,* i.e. meeting the needs of individual users. Differentiation can be difficult to deliver in real life play situations as children are often aware that they have been assigned an easier task than others. Therefore, differentiation can often stifle motivation. However, differentiation is not so evident in a video game environment. False positives (Wulf, 2010) are easily supported without the user's knowledge. Essentially, participants who presented with motor difficulties were awarded additional points which meant that ultimately their scores we comparable to others in the class. A number of parameters were altered including the rate of the ball or the height of a target. These changes were so subtle that the user often didn't realise. This means that the less fit or agile child can still achieve a level of success seemingly on par with their peers and retain a high level of motivation.

From a motivational standpoint, children were stimulated by visual effects and feedback including score systems and timers that are typically not available in real life play situations. Adaptable video games for locomotor acquisition, outlined in this study, were deployed through an adaptive process between game and teacher. This meant that the teacher was always present and that games were adapted to suit individual learner needs (often without the user's knowledge). This means that video gameplay came with additional expert feedback and instruction that prevented ingrained errors. That is, if a user was not performing accurate skill criteria, they would receive feedback to let them know what they needed to learn. This differs to self-generated practice, where the learner is not always aware that there is something to be learned (Day, 2010). Thus, a reminder of how valuable and important the teacher is in the deployment of video games for locomotor acquisition. The teacher's role is particularly interesting since the human role was initially considered to be a temporary negotiation of technical limitations. That said, improvements to 3D sensor technologies could see the role of the teacher no longer classed as necessary. However, the results of this thesis suggest otherwise. That is, some parts of the adaptive process may well become more sophisticated but an ideal design blueprint of video games for locomotor acquisition in the classroom, maintains the adaptable quality and empowers the teacher to be at the centre of deployment. Over the course of the research period, there has been a large volume of data collected that informs an 'ideal design blueprint'. The penultimate section will outline this blueprint in full.

6.6 THE FUTURE OF VIDEO GAMES FOR LOCOMOTOR ACQUISITION

The results of this research speak to the effectiveness of a theoretical design framework, PaCMAn, which supports locomotor training and acquisition in a video game environment. In this study, several parts of the PaCMAn framework were facilitated through the use of a human adaptive component, the teacher. However, PaCMAn is designed to be *agnostic* meaning that it has the potential to be delivered in different ways. The PaCMAn framework was never intended to be limited to the games outlined in this research. Conversely, sensor technology is improving at such a rapid rate that, in the near future, affordable sensors will be capable of the accuracy required for computer lead locomotor assessment. Interestingly, teachers who participated in this study stated that they would be keen to hand over responsibility of motor assessment to the computer. At present, Kinect V1 and V2 both struggle with an accurate measurement of locomotor criteria (*the process*) owing to the multi-orientation movement, dominant use of the lower limbs, and the speed with which consecutive skills are performed. However, the Kinect (V2) already demonstrates the capacity to assess *the product* of user performance (fitness and effort) as well user motivation levels; the two remaining parameters for assessment in PaCMAn. For example, Kinect V2 captures data across a larger field of view. This means that it can interpret the amount of force being applied by the body to the floor. This also allows Kinect to track the speed and overall effort of movements. Additionally, the Kinect V2 has the capacity to monitor heart rate by using the colour cameras to measure how flush a user's skin appears. This kind of data captures the fitness level of the user and/or the point of fatigue. The tracking of facial features by the Kinect V2 also means that it can potentially detect if the user is smiling or frowning (happy, sad or neutral) (Wang et al., 2015). This kind of data could be utilised reveal the user's level of motivation. Theoretically, improved sensor accuracy could see a full user assessment carried out and the parameters of gameplay adjusted in line with individual user needs. This means a PaCMAn framework could potentially be supported in its entirety through video gameplay without the need for a human adaptive component (the teacher). With that, video games for locomotor acquisition could develop into a new genre of exergames that require little more in terms of deployment than 'power on' and 'play'.

However, feedback from this research suggests that teachers value being a part of the deployment process. Furthermore, quantitative results highlight the positive affect that teacher involvement has on acquisition. Whilst in theory, a video game may be able to provide feedback and instruction suited to individual user needs, the reality is a computer game will never understand the nuances (e.g. personality or background) of the learner in the same way as a human. Ultimately, it appears best to improve upon the ways in which we support the 'human adaptive component', empower them to take ownership of their role in deployment, instead of trying to remove them altogether.

Each part of the deployment process involving the teacher (assessment, adaption, instruction and feedback) presented with its own set of (low level) difficulties. It should be noted that, collectively, these difficulties present as a barrier with the potential of deterring the teacher from utilising video games for locomotor training in the classroom. One teacher in this study commented that if the deployment process could first be viewed (through a video demonstration) and not read (via Teacher Adaption and Deployment Guide) it would have made her feel more confident from the outset. This sparks the possibility of a 'deployment demonstration' through a training video or *training level* within the game itself. Indeed, a number of popular games on the market feature an element of training that aims to instruct the user on the specifics of gameplay and to practice the skills they need to achieve success in the virtual world. This principle could be applied to video games for locomotor acquisition. For example, in Call of Duty 4 (Microsoft, 2007) there is a specific training level and introduction provided for the user. It has been developed on a narrative in which the user portrays a soldier who has to negotiate an obstacle course. The course is completed by listening to the instructions of a *commander*. The course is therefore a tutorial in the guise of a story or *level*; it works both ways (Sylvester, 2013). A tutorial within video games for locomotor acquisition could also work in multiple ways to support users with game objectives and motor outputs, as well as guiding the teacher through the process of deployment; from assessment, to adaption, to feedback and instruction.

Teachers involved in this study commonly referenced the provision of feedback and instructional as an intuitive and natural process. Conversely, they expressed difficulty delivering instruction and feedback that had an external focus, i.e. referencing the effects of user movements ("could you get down lower?") as opposed to the movements themselves ("bend your knees"). Many games provide instruction and feedback to the user in the form of text messages and audio instructions during gameplay (Sylvester, 2013). Some similar modus operandi, could be useful to support teachers with effective deployment of instruction and feedback. This was also suggested by teacher #2 (table 5.5). That is, video games have the capacity to deliver messages or hints to prompt the teacher on appropriate instruction/feedback. Then, the teacher could bring these words to life and adjust them in line with their own understanding of individual user needs, e.g. deliver them in a specific tone of voice etc.

Over the course of the research period, several teachers referenced *an understanding* of the users. This innate sense of care for the user was observed in several ways but in particular through the aforementioned, tone of voice. Indeed, all teachers who took part in this study adapted their tone of voice in line with individual user needs. Teacher instruction and feedback ranged from calm, to more animated, to highly enthused, depending on the learner's personality or learning style. Teachers also noted that on any given day they may have to employ a different tack with the same user. That is, some days, children present as unable/unwilling to attend in class. These 'off days' required a different approach to ensure that learning still occurred. Ultimately, emotional nuances require a 'human touch' in order to maintain user motivation. However, Sylvester (2013) refers to game design features that also offer *emotional life support* for novice users who are unmotivated or present with difficulties. He suggests low skill emotional triggers can be used to support an inexperienced user, e.g. fascinating characters, interesting music or beautiful art/graphics. On their own, these triggers are not enough; in an ideal (gaming) world, a user would be supported by aforementioned low level *emotional triggers* combined with additional instruction/feedback effectively deployed by an emotionally astute teacher. This could greatly increase user motivation.

Motivation itself is outlined as a parameter of assessment in PaCMAn. The teacher is asked to record if the user is willing or unwilling to attend (by observation or direct questioning). Theoretically, users will attend once game outputs and expected effort is in line with their capability. Therefore, the maintenance of an appropriate level of effort became a focus of deployment during the action research period. The majority of children in this study demonstrated a willingness to attend over the eight-week research period. However, in order to keep children interested in gameplay for even longer periods (beyond that of the research period) the principle of 'motivation' requires further attention. For example, in this study where children presented as unmotivated, they were swayed by the teacher through an altered tone of voice (deployment form, appendix 2.2) or by affording the user more choice in the gaming process – e.g. user chose game and/or length of play (deployment form, appendix 2.1). However, more sophisticated game designs of the future could support motivation by delivering graphic/character options in line with children's interests. The user may be enabled to choose a character of their choice or a game background they find appealing. In addition, recent studies on reading fluency demonstrate the positive impact that recording and listening to oneself reading has on learner motivation. Essentially, audio recordings capture the learner's interest and motivate them to make adjustments until they are happy with the finished recording (NCTE, 2012). In the same way, it could be useful for users to video record their motor outputs and view/self-evaluate their efforts leading to an increased motivation for further practice/gameplay. Given that 3D sensors are essentially cameras, this platform for self-evaluation and motivation could become a reality with more sophisticated design. There are a whole host of potential design elements as yet unexplored that could be adopted and adapted to help motivate user participation in video games for locomotor acquisition over extended periods of time.

The adaptable video games developed for this thesis (Locogames), allow 'time' to be adapted by the teacher who adjusts the length of play based on the user's fitness level. However, in order to fit within a class timetable and due to the unpredictable nature of a school setting, teachers will always benefit from being able to control the length of play affording them further flexibility. Essentially, teachers typically have to alter the length of most class lessons 'on the go'. Even though the likelihood is that future 3D sensor developments will be able to dictate an appropriate length of play (or target height etc.), these parameters may not be in line with *teacher* needs or the needs of the classroom timetable. In this scenario, as suggested by one of the teachers who took part in this study, it would be useful for (all) features to be adaptable by simply clicking (or dragging, or sliding) the feature or a button and adapting a target height, game length, game score etc. In his book, *Designing Games*, Sylvester (2013) writes: "Every additional amount of headroom and legroom we put into the elastic spectrum of a game means another group of players won't be subjected to a frustrating failure or skill ceiling" (p.73). Ergo, facilitating adaptable game design features affords the teacher ample opportunity to adapt games to meet user needs.

As previously stated, video games developed for this study were not intended to be sophisticated or a finished product. However, they have been utilised in several classes and several schools outside of the research period largely facilitated by the fact that the software required to run these games is free. This 'cost factor' is a crucial part of bridging the gap between research and practice. After all, there are already wearable sensors capable of tracking gross motor skills effectively, the problem is they are simply not affordable (or logistically viable) for schools to purchase. Thus, this thesis focused on 'affordable' Kinect sensors. This sensor is already owned by some teachers and students in the school who use it for recreational purposes with a games console. If purchased by a school, affordable sensors offer value for money as they are easy to store and share between several teachers/classes. In addition, most classrooms are moving towards (interactive) whiteboards connected to laptops. This means that video games for use in the classroom would benefit from the ability to run on a laptop as opposed to a console. Essentially the cost of these games should consider the limited budgets on offer to schools and take advantage of the hardware/software already used in the classroom setting.

A final area to be considered for future developments of video games for locomotor acquisition is *space*. Essentially, the games developed for this thesis could theoretically be deployed in small classrooms. However, in reality Kinect V1 picks up bodies other than that of the user and games freeze as a consequence. This is a considerable inconvenience. However, Kinect V2 allows for six 'skeletons' to fit in the frame at once. It can more accurately differentiate between users and non-users. This allows for the sensor to be used in smaller spaces. It also potentially supports multiple/simultaneous assessments. Future versions will potentially identify users at the start of the game and overlook slight movements from nonusers. This would make the deployment process significantly easier for the teacher, particularly in smaller spaces.

In summary, the future of video games for locomotor acquisition has the following blueprint (table 6.1):

Table 6.1 video games for locomotor acquisition: Design Blueprint

Learner	Assessment	- Assessment level disguised as a training level instructing the user on how to play and also guiding the teacher on deployment - Assessment carried out by improved 3D sensors capable of accurately identifying skill criteria, force and fitness - Assessment can be carried out on multiple users simultaneously - Computer also gauges motivation by asking for user assent, assessing user facial expressions and measuring user effort (comparative over time) - All aspects of assessment are tracked and stored, building an assessment record of users over time
Practice	Structured	- All design features are adaptable with the click, slide, drag of a button - Practice is structured by altering these features based on results of user assessment - Teacher also has the capacity to alter parameters (design features) to meet additional needs (user or classroom e.g. space/timetable) - Games have multiplayer option - Game monitors the schedule of play and prompts a suitable variability and distribution of gameplay based on user needs
	High Effort	- Aspects of design e.g. game characters, music or backgrounds chosen by users to facilitate motivation (low-level emotional triggers) and maintain high effort - Game detects skills performed inaccurately by the users and prompts them to adjust their output - Game provides the teacher with useful feedback/instruction prompts that can be delivered to the user to improve skill effort
Instruction	Structured	- Game prompts are largely intended for the teacher who brings them to life with emotionally astute instruction - Teacher can choose the timing and schedule of prompts or 'turn off' computer instruction altogether
	Multi Type	- Teacher and computer provide verbal/text instruction - Teacher provides addition physical demonstrations - Demonstrations also provided for 'in game' through sophisticated graphics
Feedback	Structured	- Game provides text and audio feedback - Teacher brings computer feedback 'to life' with an adjusted tone of voice, depending on individual user personalities - Game feedback is high or low frequency depending on user needs - Teacher can choose frequency or turn off computer feedback altogether
	Multi Type	- Specific movement effect language appears as text messages within game to prompt teacher - Game contains scoreboard comparing all users for normative feedback - Scoreboard can be bypassed or removed by teacher - Teacher can alter scoring system to facilitate false positives

6.7 FUTURE WORK TO EXTEND THE RESEARCH

This thesis has outlined a PaCMAn framework that can be used to underpin the design and development of adaptable video games for locomotor acquisition. The effectiveness of the framework can be observed through statistically significant improvements demonstrated by the users from pretest to posttest. Several parts of the PaCMAn framework were facilitated in a video game environment through the use of a human adaptive component (the teacher). Essentially, the teacher delivered parts of the PaCMAn framework that the system could not (owing to technical limitations). The teachers observed in this study demonstrated an ability to effectively deploy video games for locomotor acquisition in the classroom. That is, they were capable of doing all of the things asked of them by the Teacher Adaption and Deployment Guide. Several steps were omitted from the guide, and had to be prompted and guided by the teacher. These additional steps should be included in future iterations of the guide.

Whilst the games for this thesis were not intended to be sophisticated, even still they could be utilised by other teachers to support locomotor acquisition in the classroom. However, even though they may work in theory; in practice, there are many parts to the deployment process (e.g. downloading drivers, and installing hardware etc.) that would likely deter most teachers from fully adopting video games for locomotor training purposes in the classroom. In order to truly bridge the gap between research and practice, there are several areas for future work that require (significant) attention

(i) A refined PaCMAn design framework

(ii) Development of a sophisticated series of adaptable games for locomotor acquisition

(iii) An evaluation into the effects improved locomotor acquisition (facilitated through video gameplay) has on performance elsewhere

6.7.1 REFINEMENT OF PACMAN FRAMEWORK

This thesis demonstrated the positive affect that adhering to a PaCMAn framework has on locomotor acquisition. PaCMAn was articulated through a systematic analysis of the literature. The deployment of video games was centred on delivering every principle and condition in PaCMAn through a video gaming experience. However, future work should evaluate if all PaCMAn are indeed crucial for acquisition. That is, how would the omission of certain principles and conditions (e.g. knowledge of results or normative feedback) affect user performance? More research is required into identifying optimal principles and conditions, as well as the optimal combination of principles and conditions for motor training and acquisition. Overall, a need exists to evaluate PaCMAn further and decipher an ideal outline which may or may not include all of the principles and conditions currently included in the framework.

Refining the PaCMAn framework leads to a more refined deployment process and potentially smoother implementation in the classroom setting. A refined PaCMAn framework would also affect development of future, more sophisticated versions, of video games for locomotor acquisition. This means, future work should potentially *begin* with further research into PaCMAn before anything else.

6.7.2 SOPHISTICATION OF VIDEO GAMES FOR LOCOMOTOR ACQUISITION

Once PaCMAn has been refined to its most optimal form, sophisticated video games for locomotor acquisition could be developed using the design blueprint articulated in Table 6.2. This development should also include the latest and most accurate 3D sensor technology, whilst maintaining the importance of a human adaptive component, the teacher. Indeed, a sophistication of video games for locomotor acquisition does not aim to curtail the role of the teacher but rather, to empower them further by allowing them to fulfil their role with even more ease and effectiveness. Therefore, the selling point of sophisticated video games for locomotor training and acquisition, is not necessarily that they bring about significant gains in locomotor skills, but that they *enhance* the training and acquisition process whilst still allowing the teacher to, effectively, take the lead.

6.7.3 ANALYSIS INTO EFFECTS OF GAMEPLAY ELSEWHERE

In order to prompt deployment of a locomotor skills training regime, there has to be a level of 'buy in' from teachers. This starts with truly valuing the importance of effective locomotor skills. To date, research has focused on the fact that poor locomotor skills affect health and participation in sport. However, potential links between improved locomotor acquisition and improved performance in other (cognitive) domains, could increase the value of having effective locomotor skill even further. A key part of *future work* may well be to evaluate, and demonstrate, the effects of video gameplay, not only on locomotor skill performance, but on potentially related tasks.

Ultimately, the inspiration for this thesis came from my experiences as an infant class teacher and a reoccurring phenomenon of teaching children who demonstrated co-morbid deficits in locomotor skills, reading, speech, and/or mathematics. In recent years, literature also points towards causality between specific subsets of gross motor performance and achievements in other domains. Poor locomotor acquisition has been linked to poor reading fluency, speech and language, health and behaviour. Thus, video games for locomotor acquisition could be used to facilitate further investigations into these potential subset links (e.g. locomotor skills and reading automaticity). At present, this type of research is compromised by the fact that researchers struggle to identify an effective locomotor training platform (easily deployed, supports improved performance etc.). Ergo, video games for locomotor acquisition could be used for research purposes and facilitate an evaluation into the effects of improved locomotor performance on specific cognitive tasks. Every subset link that these games help to support, simply enhances their worth and fosters further ‘buy in’ from teachers. In the future, games similar to those outlined in this thesis, may be retitled and remarketed as a platform not only to support locomotor training and acquisition, but to bring about change in potentially related cognitive tasks. Thus, enabling students to hop.skip.jump.game their way to new forms of learning.

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APPENDICES

APPENDIX 1

FIRST ANALYSIS: PAPERS WITH EMPIRICAL EVIDENCE TO SUPPORT IMPROVED GROSS MOTOR ACQUISITION

Note: [Square brackets**]** indicate that principle or condition was implied, not stated

Authors: (Summary 1) **Maas et al., 2008**
Description: *A critical review of principles for motor acquisition to support treatment for motor speech disorders*

(Principle)	**Conditions**	**Description**
Pre-Practice	- Model task - Describe task	Information about the task and its relevance
Structure of Practice	-	Structure of practice is determined by the amount, complexity and variability
Practice Amount	- Large - Small	The number of practice trials
Practice Distribution	- Massed - Distributed	Practice a number of trials all at the same time or over a period of time
Practice Variability	- Constant - Variable	Practice of the same or different targets
Practice Schedule	- Blocked - Random	Multiple movements practiced in blocked or random trials
Attentional Focus	- Internal - External	Focus on body movements (names body parts) or the movement effect (names external features)
Feedback Type	- Knowledge of performance - Knowledge of results	How movement was performed, results of the movement
Feedback Frequency	- High - Low	After every trial, or only some
Feedback Timing	- Immediate - Delayed	Provided immediately or delayed

Authors: (Summary 2) **Wulf & Shea, 2002**

Description: Review of Principles that support the learning of motor skills and examining a generalization across complex skills

Note: *Task complexity is relative: Locomotor skills (or specific subset skills) may be classed as simple for some learners but complex for others*

Principle	**Conditions**	**Description**
Practice Distribution	• Massed • Distributed	Practice a number of trials all at the same time or over a period of time
Practice Schedule	• Blocked • Random	For complex tasks, practicing several skills in random order is supported. For more basic tasks, blocked practice is preferable
Attentional Focus	• Internal • External	Focus on body movements (names body parts) or the movement effect (names external features)
Feedback Frequency	• High • Low • Reduced Feedback	Reduced feedback may make practice too challenging and degrade performance High FF supports learners of complex tasks
Feedback Organisation	• [Blocked or random]	Feedback focuses on one aspect of performance e.g. knee bend in a jump, or random aspects e.g. all jump criteria

Authors: (Summary 3) **Lee & Schmidt, 2008**

Description: Book chapter informed by empirically supported studies:

Understanding the acquisition of motor skill with practice or experience

Principle	**Conditions**	**Description**
Amount of Practice	• Large • Small	The number of practice trials
Practice Distribution	• Blocked or • Random	Continuous practice of the same skill or random practice of different but related skills
Practice Variability	• Equal • Variable	Practice of the same or different targets. Variable practice deemed beneficial for transference. Variability constitutes target criterion or criterion around it.
Feedback Type	• Knowledge of performance • Knowledge of results	How movement was performed, results of the movement
Feedback Frequency	• High • Low	After every trial, or only some
Feedback Timing	• Concurrent • Terminal	Feedback provided during practice, or after practice. Depends on length of practice and if there is enough time for learner to digest information
Composition of Practice	n/a	Refers to the conditions that make up the practice

Authors: Sidaway et al., 2012

Description: Effects of Interactions between Feedback Frequency and Task Difficulty on children's object control acquisition
Note: Specific to children, however, cohort are 10 years old at the upper end of the developmental period.

Principle	**Conditions**	**Description**
Practice Distribution	• Blocked or • Random	Continuous practice of the same skill or random practice of different but related skills
Practice Variability	• Equal • Variable	Practice of the same or different targets. Variable practice deemed beneficial for transference. Variability constitutes target criterion or criterion around it.
[Practice Complexity]	• Functional Difficulty in line with • Nominal Difficulty	FD relates to the actual skill level of the learner, ND refers to the characteristics of the skill
Feedback Type	• Knowledge of performance • Knowledge of results	Feedback included information relating to how movement was performed, results of the movement
Feedback Frequency	• High • Low	High FF (after every trial) is detrimental for adults but beneficial for children with significant learning difficulties. Also significant support if task is complex
Feedback Timing	• Concurrent • Terminal	Feedback provided during practice, or after practice. Depends on length of practice and if there is enough time for learner to digest information
Structuring Practice	n/a	Conditions of practice should take into account the complexity of the task

Authors: Wulf, Shea and Lewthwaite, 2010
Description: *Motor skill learning and performance: a review of influential factors*
Findings: *Principles reviewed have informational and motivational qualities.*
Note: *Specific to motor training in adults*

Principle	**Conditions**	**Description**
Pre-Practice	• Model task • Describe task	Information about the task and its relevance
[Practice Type]	• Observation of others • Dyad Practice (in pairs)	Observation of others combined with physical practice enhances learning
Attentional Focus	• Internal • External	Internal focus promotes automaticity and movement efficiency
Feedback Type	• Normative • False-positives • Knowledge of Results • Knowledge of performance	Social-comparative feedback benefits learning. This can include the provision of false information by instructor to make learner feel as good as their peers. Feedback about how movement was performed, and results of the movement supports learning
[Feedback Schedule]	• After successful trials	Feedback after successful trials benefits learning.
[Feedback Timing]	• Self-Controlled Feedback	Feedback that is delivered when asked for by the learner

Authors: Sweeting & Rink, 1999

Description: The effects of direct instruction and environmentally designed instruction on the process and product of a fundamental motor skill
Note: Focuses on the acquisition of a standing long jump, concerned with *process* and *product* of skill. Paper is also child specific

(Principle)	**Conditions**	**Description**
Learner Assessment	• Process [skill criteria] • Product [strength] • Environmental testing condition	Intervention should improve process and product e.g. jump criteria and length of jump. Both assessed at baseline prior to study. Young inexperienced users benefitted from an environmental testing condition.
[Pre-Practice]	• Physical Demonstration • Visual Demonstration	Demonstration also given via video paused on specific criteria
Practice Amount	• 60 practice trials [High or Low]	The number of practice trials in this study were high
[Practice Complexity]	• Individual parts • Whole [Parts or whole skill] • Force [strength]	Children first practiced the initial parts of the jump, then the last part of the jump, then whole skill. Task should also elicit child's maximum level of force
[Instructional Types]	• Direct Instruction • Demonstration • Verbal Cues	Direct Instruction is teacher lead, sets clear goals, is stepwise and sequential – includes demonstration and verbal cues
[Instructional Variability]	• Constant • Variable	Instruction has a constant focus or variable focus. Instructional type is constant or variable
[Feedback Type]	• Knowledge of performance	Information relating to how movement was performed,
[Feedback Focus]	• Use of verbal cues	Consideration for feedback language
[Feedback Frequency]	• Immediate • When required	Feedback given immediately or when teacher decides it is needed (observation)

Authors: Wulf, 1991

Description: Examines the effects of practice type on motor learning and investigates if there is an optimal way to structure practice

Principle	**Conditions**	**Description**
[Pre-Practice]	- Model task - Describe task	Information about the task and its relevance
Practice Variability	- Same skill but with different levels of force [Constant or variable]	Same skill performed with increased effort over time
[Practice Schedule]	- Blocked - Random	Multiple movements practiced in blocked or random trials
Feedback Type	- Procedure Explained [Verbal Demonstration] - Procedure Demonstrated [Physical Demonstration] - Knowledge of Results	How movement was performed, results of the movement
[Feedback Frequency]	- After trials [High or low]	After every trial, or only some
[Feedback Timing]	- After trials [Immediate or delayed]	Provided immediately or delayed

Authors: Wulf et al., 2010
Title: Frequent external-focus feedback enhances motor learning
Specific Findings: Paper found that feedback given after every trial with an external focus (movement effect) improved acquisition , transfer and retention

Principle	**Conditions**	**Description**
Learner Pretest	• Maximum throwing distance [strength]	Baseline assessment of learner strength
Pre-Practice	• Verbal/physical demonstration	Provision of demonstrations for learner's prior to practice
[Practice Amount]	• 30 practice trials • [Large or small]	Large amount of practice trials
[Practice Schedule]	• Blocked • Random	Multiple movements practiced in blocked or random trials
[Instruction Type]	• Verbal Demonstration • Physical Demonstration	Both verbal and physical demonstration provided for the learner
Attentional Focus	• Internal • External	Feedback specifically references movement effect not body parts
Feedback Frequency	• High • Low • Frequent • Infrequent	High or Low Frequency feedback
[Feedback Timing]	• Immediate • Delayed	After every trial, or only some (every third trial)

Authors: Muratari et al., 2013

Description: Motor learning for upper extremity rehabilitation

(Principle)	**Conditions**	**Description**
Measurement of Motor Skill	• Individual characteristics	Information about the learner's capabilities
[Amount of Practice]	• Regular practice	The number of practice trials
[Practice Effort]	• Whole skill • Parts of the skill	Novice learners benefit from developing a skill in parts
[Practice Variability]	• Constant versus variable	Practice of the same or different targets
Mental Practice	• Cognitive rehearsal	Visualising the skill and its parts before practice
Specificity of Practice	• Meaningful to individual	Focus is on a skill/parts of a skill that the learner needs to acquire
[Feedback Type]	• Knowledge of results • Knowledge of Performance	How movement was performed, results of the movement
Feedback Composition	• Descriptive or Prescriptive • Verbal or Physical	Feedback is structured and given in different ways
[Instruction Types]	• [Modelling] • Manual guidance	Instruction is structured and given in different types of ways

Authors: **Branta and Goodway, 2003**

Description: The effect of a motor skill intervention on fundamental movement skills of disadvantaged pre-school children

Principle	**Conditions**	**Description**
Learner Assessment	• Performance level of locomotor skills • Verbal assent	Information about the learner's capabilities
[Practice Amount]	• Sustained practice	The number of practice trials
[Practice Challenge]	• Challenges children at their own level	Pushes learners but not beyond their level
[Practice Complexity]	• Developmentally Appropriate Practice • Individualised • Challenges children at their own level	Practice that meets learner needs
[Instructional Type]	• Effective Instruction • Direct Instruction • Demonstration	Multi type instructional approach
[Structured Instruction]	• Instructionally Appropriate	Instruction that meets individual needs
[Feedback Type]	• Positive corrective feedback [knowledge of performance] [knowledge of results]	How movement was performed, results of the movement
[Feedback Focus]	• Use of key words [internal focus]	Consideration for feedback language

Authors: Fahimi et al., 2013

Description: The Effect of Four Motor Programs on Motor Proficiency in Boys 7-9 Years

Principle	Conditions	Description
Assessment Motor Ability	• Identify developmental stage • Identify motor skill proficiency	Information about the learner's capabilities and thus, developmental stage
Observational Assessment	• During Play • During Practice	Informal noting of child's motor ability
[Practice Schedule]	• Sufficient time for practice • Every other day	The number of practice trials
[Practice Variability]	• Free play activity or steady practice • Multiple skill practice	Practice of multiple skills through free play and steady practice
[Practice Complexity]	• Developmentally appropriate practice • Match skill proficiency	Practice that meets learner needs
[Instructional Type]	• Developmentally appropriate	Instruction is in line with the child's developmental stage
[Feedback Type]	• Encouragement	Feedback to encourage child

Authors: **Fairbrother et al., 2012**

Description: Effects of self-controlled feedback on motor learning in both high and low activity individuals

Note: Participants are young adults which means positive findings do not necessarily translate to young children.

Principle	**Conditions**	**Description**
[Learner Assessment]	• Activity level • Energy Expenditure [Fitness level]	Individuals with low activity level potentially have less motor experience than individuals with high activity level. Practice conditions will differ depending on baseline activity level
[Practice Amount]	• 60 practice trials [High or low]	The number of practice trials
[Practice Schedule]	• 10 blocks [Blocked or random]	Multiple movements practiced in blocked or random trials
[Practice Effort]	• High energy expenditure versus low energy expenditure	Energy or effort required during practice depends on baseline energy expenditure of learner
[Instructional Type]	• Direct Instruction • Demonstration (written & verbal)	Multi type instructional approach taken
[Feedback Type]	• Knowledge of Results	Results of the movement relayed to learner
[Feedback Frequency]	• Self –controlled • High or Low	After every trial, or only some

Authors: French et al., 1991

Description: Effects of practice progression on gross motor skill acquisition

Notes: Paper also includes a discussion on the importance of teacher manipulating task to suit individual learner needs. Includes empirical evidence to outline best conditions adhering to task complexity

Principle	**Conditions**	**Description**
[Practice Complexity]	• Parts (if skill is complex) • Progression • Whole skill (if skill is low organisation)	When learning complex motor skills, the learner is best served practicing in parts and progression, towards whole skill (Naylor & Briggs, 1963)
Practice Amount	• Large • Small	The number of practice trials
[Practice Effort]	• High • Low	Practice is focused on effort and improvement
[Practice Variability]	• Repetition of skill • Sequence one skill with another [Constant or Variable]	Practice of the same or different target. Repetitions of same skill for children with no experience
[Instruction Types]	• Verbal description • Physical demonstration • Task cues	Instruction outlined is mainly demonstrative

Authors: Broker, Gregor & Schmidt, 1993

Description: Impact of extrinsic feedback and different feedback schedules on development of motor patterns (specific to cycling) with young adults (college students)

Notes: Includes – graph for user outlining the force applied during task allowing them to adjust accordingly. In same way gamers could track force of the jump via character on screen.

Feedback timing may not be as sensitive as was once thought (supports more general, high or low label)

Principle	**Conditions**	**Description**
Observational Assessment of Learner	• Force applied [Strength – Product] • Parts of the skill [Skill Criteria – process]	Information about the learner's capabilities
[Amount of Practice]	• Regular practice	The number of practice trials
[Practice Complexity]	• Focused on Pedalling [**Parts** versus whole skill] • Modified Force [High effort v. low effort]	Novice learners benefit from developing a skill in parts. High effort maintained by modifying force to meet learner capabilities
[Practice Variability]	• Variable Force [Constant versus variable]	Practice of the same task with variable 'force' demands.
Specificity of Practice	• Meaningful to individual	Focus is on a skill/parts of a skill that the learner needs to acquire
[Feedback Type]	• Description of Technique [Knowledge of Performance] • Graph of force applied [Knowledge of Results]	How movement was performed, results of the movement
[Feedback Timing/Schedule]	• Concurrent • Terminal	FB given during and after trials. Terminal FB (after trials potentially supports retention)
Feedback Composition	• Graphed feedback [**Visual,** Verbal, Physical]	Feedback includes visual KOR – with a graph outlining force applied
[Instruction Types]	• Verbal Description [Demonstration]	Pedal force and cycling parts are described before trial

Authors: Theeboom et al., 1995

Description: Motivational Climate and Motor Skill Development in Children's Sport: A Field-Based Intervention Study

Notes: Builds on the work of (Arnes1992) to provide empirical evidence that suggests the provision of a **mastery motivational climate** will maximize enjoyment, perceived competence, and intrinsic motivation in children

(Principle)	**Conditions**	**Description**
Assessment of Learner	• Motivation - Intrinsic or extrinsic - Positive or negative	Assesses the motivational status of the learner. Results have an impact on the type of instruction and feedback
[Practice Effort]	• High • Low	Refers to different levels of effort required. Depends on individual learner
[Practice Variability/Complexity]	• Extensive progression [Constant or Variable]	Skills practiced build incrementally. In this way, parts and progression typically related to complexity are a related to the practice variability
[Feedback Type]	• Norm reference • Corrective Feedback [Normative Feedback]	The *construct of competence* outlined by Nicholls' (1984, 1989) is discussed. According to Nicholls, individuals are motivated to demonstrate high ability and avoid showing low ability. Thus. Learners are governed by Normative feedback.
[Feedback Focus]	"You must keep your legs straight during the kick". [Internal v. External focus]	Examples of feedback iterated in this study demonstrate an internal focus and reference the body parts as opposed to movement effect
[Instruction Types]	• Mastery Motivational	Mastery motivational climate affords the learner control of what they practice. It includes shared decision-making between teacher and student. This type of learner is not bound by social comparison or ego, but driven by an intrinsic motivation to master a skill.

Authors: Garcia and Garcia, 2006

Description: Action research: Motor Development and Motor learning perspective

Notes: A summary approach using empirically supported studies. Suggests Environmental Design i.e. Equipment can be modified to facilitate the skill and allow less skilled students to be successful.

(Principle)	**Conditions**	**Description**
Learner Assessment	• Anatomical • Physiological • Motivational	Macro assessment, looking at overall makeup of the learner
Practice Challenge Practice Demands [Complexity]	• High or Low Effort • [Whole skill or Parts of the skill]	Practice challenge based on the skill level. Equipment modified to facilitate skill level and allow less skilled students to be successful.
[Practice Schedule]	• Grouped by Skill [Blocked versus Random]	Practice of the same skill in blocks
Practice Variability	• Grouped by skill [Constant versus Variable]	Practice of same skill or a variety of skills
Feedback Type	• Corrective feedback [KOR & KOP] • Encouragement	Corrective information relating to how skill was performed
Instruction Types	• Demonstration • Direct	Multiple types of instruction

Authors: Rink et al., 1992

Description: Effects and importance of *Content Development* on complex motor skills
Note: Specific to teenagers, acquisition of an object control task (volley ball serve)

(Principle)	**Conditions**	**Description**
[Learner] Assessment	- Skill criteria	Parts of the volley ball serve assessed pre, interim and post research period
Content Development [Practice Complexity]	- In Parts and Progression - Whole Skill	Learners of complex skills should receive a progression of increased difficulty, essentially focus on parts of the skill and build to a full performance.
Type of Practice	- Extension Task or - Refining task	ET is an adapted task that manipulates complexity (Parts and progression), RT involves focusing a whole skill
Practice Amount	- Number of trials - Amount of time	Practice quantified by number of trials and length of time practicing
Practice Distribution	- Blocked - Random	Practicing in parts and progression can constitute 'random practice'
Feedback Type	- Motivational Feedback - Knowledge of performance - Knowledge of results	Feedback included motivational FB, information relating to how movement was performed, results of the movement

Authors: Kim et al., 2012

Description: Effects of Feedback and Practice on the Acquisition of Novel Speech Behaviours

(Principle)	**Conditions**	**Description**
Type of Practice	- Extension Task or - Refining task	ET is an adapted task that manipulates complexity (Parts and progression), RT involves focusing a whole skill
Practice Amount	Number of trials - High or low	Practice Amount quantified by number of trials
[Practice Distribution]	- Drill [Blocked] or - Random	In this study, practicing in parts and progression constitutes 'random practice'
Feedback Type	- Motivational Feedback - Knowledge of performance - Knowledge of results	Feedback included motivational FB, information relating to how movement was performed, results of the movement
Feedback Timing	- Concurrent/Immediate - Terminal/Delayed	FB given during and after trials. Terminal FB (after trials potentially supports retention)

Authors: Badets & Blandin, 2010

Description: Effects of Feedback Schedule on Motor Learning

(Principle)	**Conditions**	**Description**
Type of Practice	• Physical practice • Observational Practice	Practice of detailed motor outputs can benefit from observational practice. However, relates more to fine motor tasks
Practice Amount	Number of trials • High or low	Practice Amount quantified by number of trials
Feedback Type	• Knowledge of performance • Knowledge of results	KOP provides information relating to how movement was performed, KOR refers to results of the movement, both have motivational impact and effect retention if too frequent (in adults)
[Feedback Frequency or Schedule]	• Bandwidth [blocked] or • Yoked [Random] [high or low]	Feedback given consistently, or only some of the time

Authors: Ranganathan & Newell, 2010

Description: Effects of induced variability of practice goals on motor acquisition.

Principle	**Conditions**	**Description**
Learner Assessment	Assessment of skill product	Study assessed the accuracy of a throw not the criteria of the throw itself
Practice Schedule	Has several dimensions and includes • Variability and • Distribution	Outlined as an overarching principle of practice variability and practice distribution
Practice Variability	• Constant versus • Variable or random	Practice of same skill or upon parts of skill. Study focused on product i.e. same target, versus variable targets
Practice Distribution	• Blocked • Random	Practicing in parts and progression can constitute 'random practice'

Authors: **Lee & Porretta, 2013**

Description: *Enhancing motor skills of children with ASD, a pool based approach*

(Principle)	**Conditions**	**Description**
[Practice Complexity]	• Modified skill • Modified environment	Instructors can manipulate task or environment relative to the learner
[Practice Effort]	• Movement direction • Movement height • Movement distance • Movement speed • Strength and balance components	Instructors can make tasks easier for beginners by modifying strength and balance components

APPENDIX 2

DEPLOYMENT FORM DEVELOPED TO EVALUATE THE DELIVERY OF PACMAN

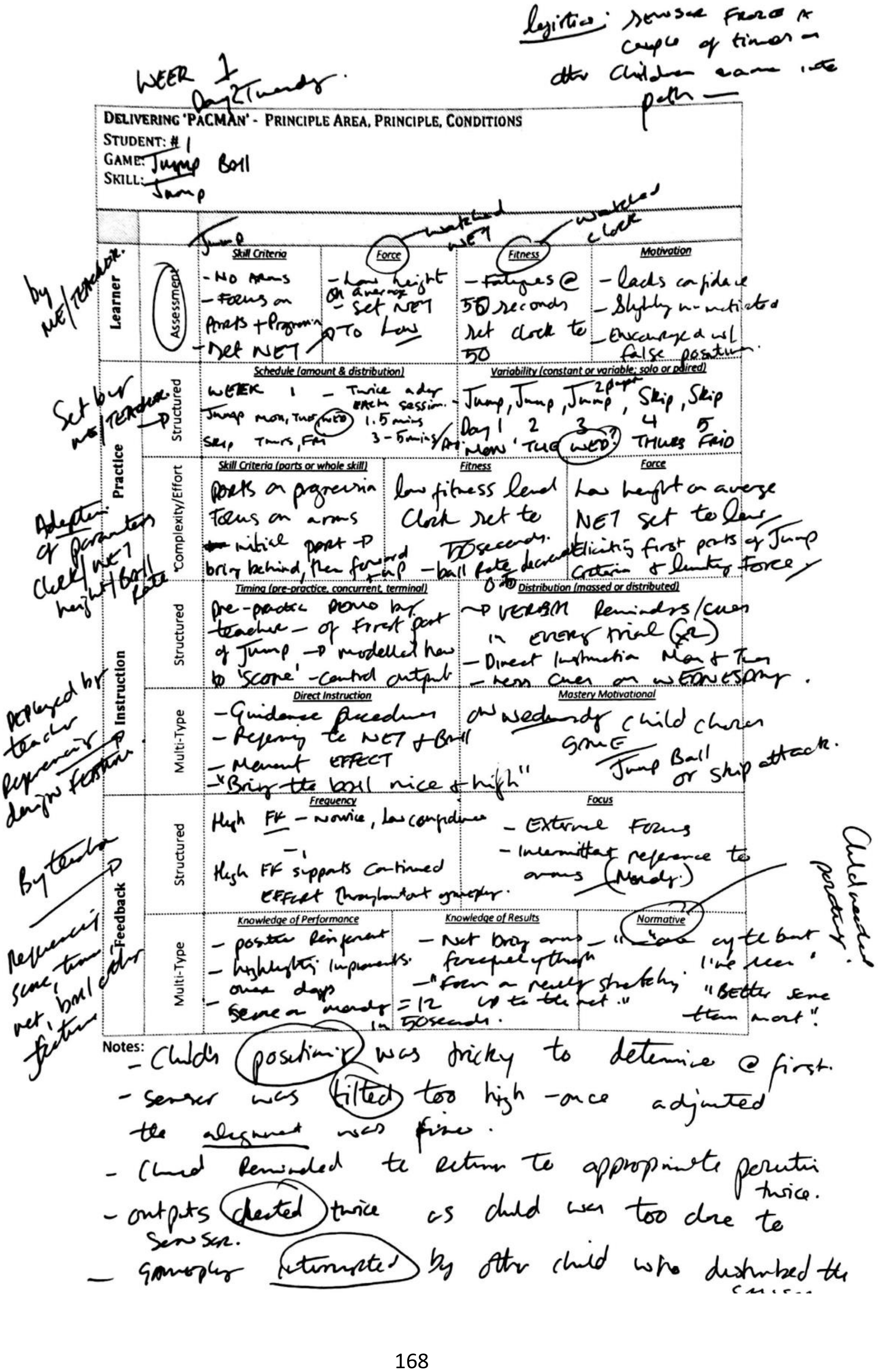
DELIVERING 'PACMAN' - PRINCIPLE AREA, PRINCIPLE, CONDITIONS
STUDENT: #1
GAME: JUMP BALL
SKILL: JUMP

Learner	Assessment	*Skill Criteria*	*Force*	*Fitness*	*Motivation*
Practice	Structured	*Schedule (amount & distribution)*	*Variability (constant or variable; solo or paired)*		
	Complexity/Effort	*Skill Criteria (parts or whole skill)*	*Fitness*	*Force*	
Instruction	Structured	*Timing (pre-practice, concurrent, terminal)*	*Distribution (massed or distributed)*		
	Multi-Type	*Direct Instruction*	*Mastery Motivational*		
Feedback	Structured	*Frequency*	*Focus*		
	Multi-Type	*Knowledge of Performance*	*Knowledge of Results*	*Normative*	

APPENDIX 2.1

SAMPLES OF COMPLETED DEPLOYMENT FORMS DETAILING DELIVERY OF PACMAN DURING GAMEPLAY

JUMP BALL



logistics: sensor froze a couple of times — other children came into path —

WEEK 1
Day 2 Tuesday.

DELIVERING 'PACMAN' - PRINCIPLE AREA, PRINCIPLE, CONDITIONS

STUDENT: # 1
GAME: Jump Ball
SKILL: Jump

Jump — watched NET — watched clock

by ME/TEACHER.

		Skill Criteria	Force	Fitness	Motivation
Learner	Assessment	- NO ARMS - FOCUS on Parts + Progression - Set NET	- Low height on average - Set NET → To Low	- Fatigues @ 50 seconds Set clock to 50	- lacks confidence - Slightly un-motivated - Encouraged w/ false positive.

Set by me/TEACHER →

		Schedule (amount & distribution)	Variability (constant or variable; solo or paired)
Practice	Structured	WEEK 1 - Twice a day EACH session Jump MON, TUES, WED 1.5 mins Skip THURS, FRI 3 - 5 mins/Att	Jump, Jump, Jump 2 player, Skip, Skip Day 1 2 3 4 5 MON TUE WED? THURS FRID

Adaption of parameters Clock/NET height/Ball rate

		Skill Criteria (parts or whole skill)	Fitness	Force
Practice	Complexity/Effort	Parts on progression Focus on arms initial part → bring behind, then forward + up	low fitness level Clock set to 50 seconds. - ball rate decreased 0 → [illegible]	Low height on average NET set to low, eliciting first parts of Jump Criteria & limiting Force

		Timing (pre-practice, concurrent, terminal)	Distribution (massed or distributed)
Instruction	Structured	pre-practice DEMO by teacher — of first part of Jump → modelled how to 'score' - control output	→ VERBAL Reminders/cues in every trial (x2) - Direct Instruction Mon & Tues - Less Cues on WEDNESDAY.

Deployed by teacher referencing → design feature.

		Direct Instruction	Mastery Motivational
Instruction	Multi-Type	- Guidance procedures - Referring to NET & Ball - Movement EFFECT - "Bring the ball nice & high"	on Wednesday child chooses GAME Jump Ball or Skip attack.

By teacher → Referencing score, time, net, ball color feature

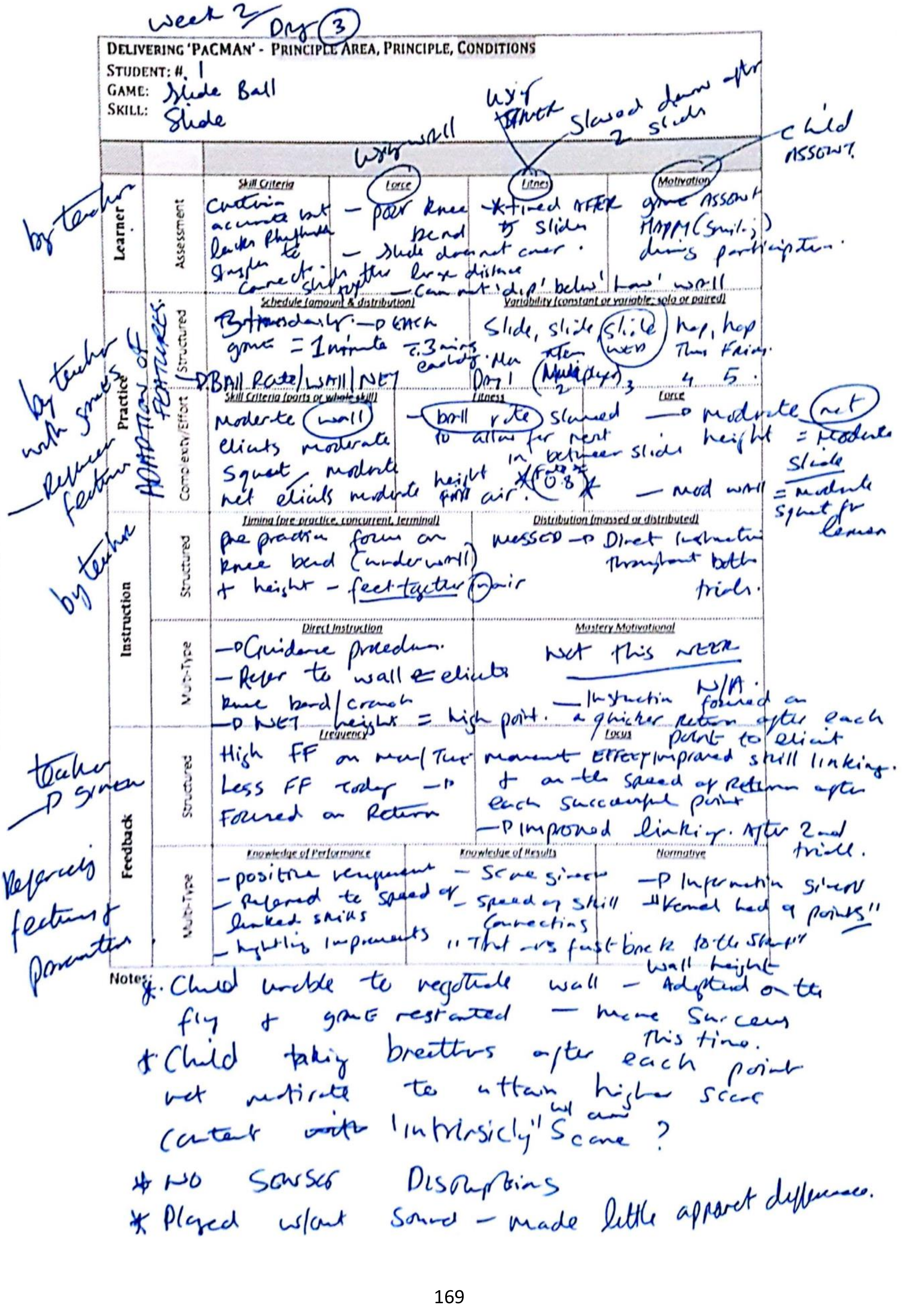
		Frequency	Focus
Feedback	Structured	High FK - novice, low confidence High FK supports continued EFFORT throughout gameplay.	- External Focus - Intermittent reference to arms (Monday.)

Child-directed positivity.

		Knowledge of Performance	Knowledge of Results	Normative
Feedback	Multi-Type	- positive Reinforcement - highlighting improvements over days - Score on Monday = 12 in 50 seconds.	- Not bring arms forward up through - "from a really stretchy up to the net."	- "[illegible] cycle but I've seen." "Better score than most!"

Notes:
- Child's positioning was tricky to determine @ first.
- sensor was tilted too high - once adjusted the alignment was fine.
- Child Reminded to return to appropriate position twice.
- outputs cheated twice as child was too close to sensor.
- gameplay interrupted by other child who disturbed the

SLIDE BALL



week 2/ Day 3

DELIVERING 'PACMAN' - PRINCIPLE AREA, PRINCIPLE, CONDITIONS

STUDENT: #. 1
GAME: Slide Ball
SKILL: Slide

w/gt wall

w/gt ~~STRETCH~~ Slowed down after 2 slides

Child ASSESSMENT

Learner	Assessment	**Skill Criteria** Continuing accurate but lacks rhythm to struggles to connect skills together	**Force** — poor knee bend — slide does not cover large distance — Cannot 'dip' below 'low' wall	**Fitness** *tired AFTER 5 slides	**Motivation** game ASSESSMENT HAPPY (smiling) during participation.
Practice	Structured	**Schedule (amount & distribution)** Bi-weekly/daily → EACH game = 1 minute c.3 mins each day. → BALL Rate/WALL/NET	**Variability (constant or variable; solo or paired)** Slide, slide (slide wed) hop, hop Mon Tues Wed Thurs Friday. Day 1 (Multiple days) 2 3 4 5.		
	Complexity/Effort	**Skill Criteria (parts or whole skill)** Moderate (wall) elicits moderate squat, moderate net elicits moderate height from air.	**Fitness** — (ball rate) slowed to allow for rest in between slides *(Force 0.8)*	**Force** → moderate (net) height = moderate Slide — mod wall = moderate squat for lesson	
Instruction	Structured	**Timing (pre practice, concurrent, terminal)** pre practice focus on knee bend (under wall) + height — feet together in air	**Distribution (massed or distributed)** MASSED → Direct Instruction throughout both trials.		
	Multi-Type	**Direct Instruction** → Guidance procedure. — Refer to wall & elicits knee bend/crouch → NET height = high point.	**Mastery Motivational** Not this WEEK N/A. — Instruction focused on a quicker return after each point to elicit		
Feedback	Structured	**Frequency** High FF on Mon/Tue Less FF today → Focused on Return	**Focus** moment EFFECT/improved skill linking. + on the speed of Return after each successful point → Improved linking. After 2nd trial.		
	Multi-Type	**Knowledge of Performance** — positive reinforcement — Referred to speed of linked skills — highlighting improvements	**Knowledge of Results** — Score given — speed of skill connections "That was fast back to the start"	**Normative** → Information given "Kemal had 9 points"	

by teacher

by teacher with games — Reference features

ADAPTATION OF FEATURES

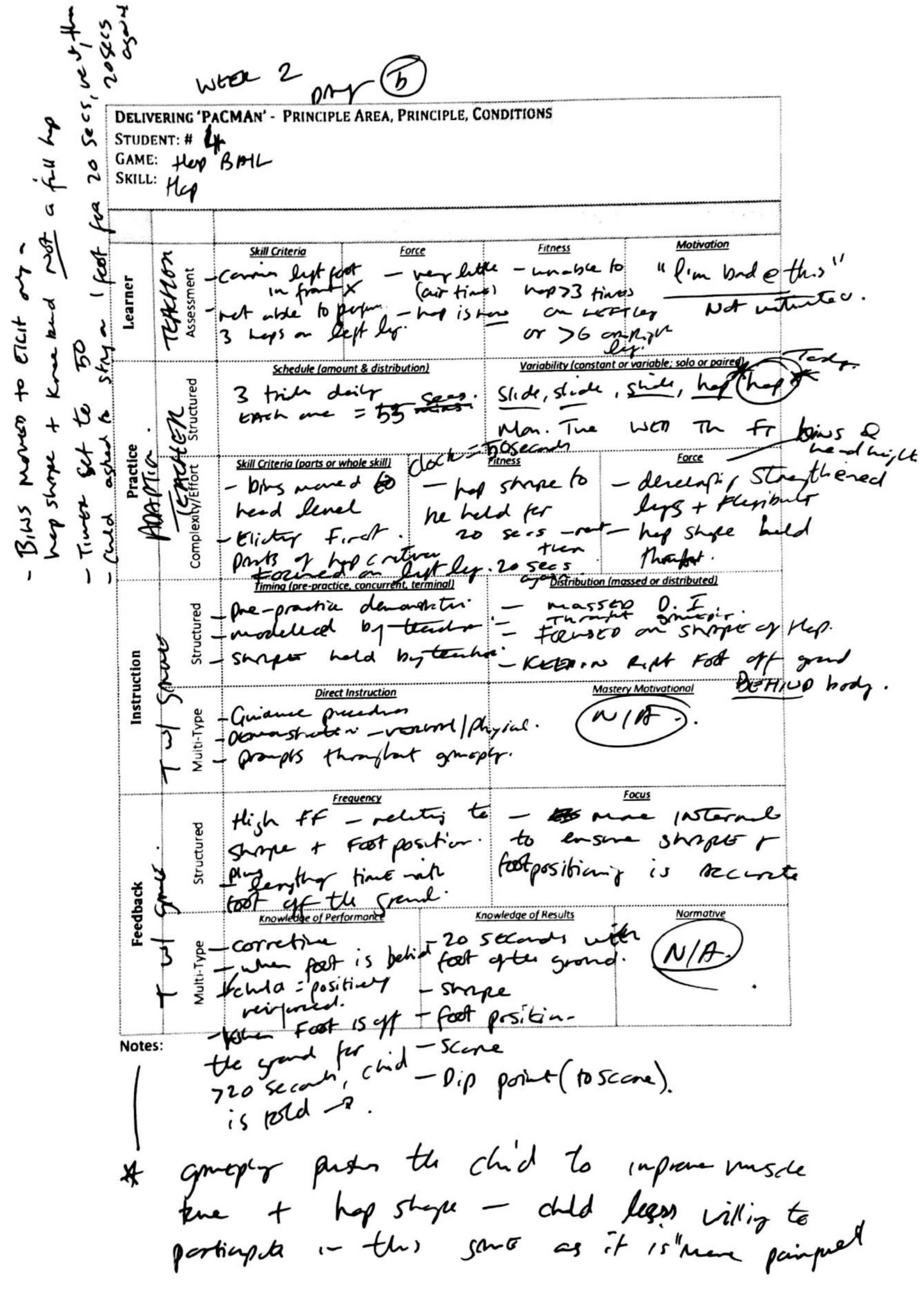
by teacher

teacher → given

Referencing features & parameters

Notes:
*. Child unable to negotiate wall — Adapted wall height on the fly + game restarted — more success this time.
* Child taking breathers after each point not motivated to attain higher score content ~~with~~ 'intrinsicly' w/ own Score ?
* NO SENSORY DISRUPTIONS
* Played w/out sound — made little apparent difference.

HOP BALL



WEEK 2 DAY (b)

- Bins moved to elicit only a hop shape + knee bend ~~not~~ a full hop
- Timer set to 50
- Child asked to stay on 1 foot for 20 secs, rest, then 20 secs again

DELIVERING 'PACMAN' - PRINCIPLE AREA, PRINCIPLE, CONDITIONS
STUDENT: # 4
GAME: Hop BALL
SKILL: Hop

Learner – TEACHER – Assessment

Skill Criteria
- Carrying left foot in front X
- not able to perform 3 hops on left leg.

Force
- very little (air time)
- hop is [illegible]

Fitness
- unable to hop >3 times on LEFT leg or >6 on right leg.

Motivation
"I'm bad @ this"
Not motivated.

Practice – ADAPTIVE. – TEACHER – Structured

Schedule (amount & distribution)
3 trials daily
EACH one = ~~55~~ 55 Secs. ~~mins~~

Variability (constant or variable; solo or paired)
Slide, slide, slide, hop hop – Today.
Mon. Tue WED Th Fr
bins @ head height

Complexity/Effort

Skill Criteria (parts or whole skill)
- bins moved ~~to~~ to head level
- Eliciting first parts of hop criteria focused on left leg.

clock = 50 seconds

Fitness
- hop shape to be held for 20 secs – rest – then 20 secs again.

Force
- developing/strengthened legs + flexibility
- hop shape held throughout.

Instruction – T w/ space – Structured

Timing (pre-practice, concurrent, terminal)
- pre-practice demonstration
- modelled by teacher
- shape held by teacher.

Distribution (massed or distributed)
- massed D.I. throughout gameplay.
- FOCUSED on shape of Hop.
- KEEPING Right Foot off ground BEHIND body.

Multi-Type

Direct Instruction
- Guidance procedures
- demonstration – visual/physical.
- prompts throughout gameplay.

Mastery Motivational
N/A.

Feedback – T w/ game. – Structured

Frequency
High FF – relating to shape + foot position.
- ~~play~~ lengthening time with foot off the ground.

Focus
- ~~[illegible]~~ more internal to ensure shape + footpositioning is accurate

Multi-Type

Knowledge of Performance
- corrective
- when foot is behind child = positively reinforced.
- when Foot is off the ground for >20 seconds, child is told ?.

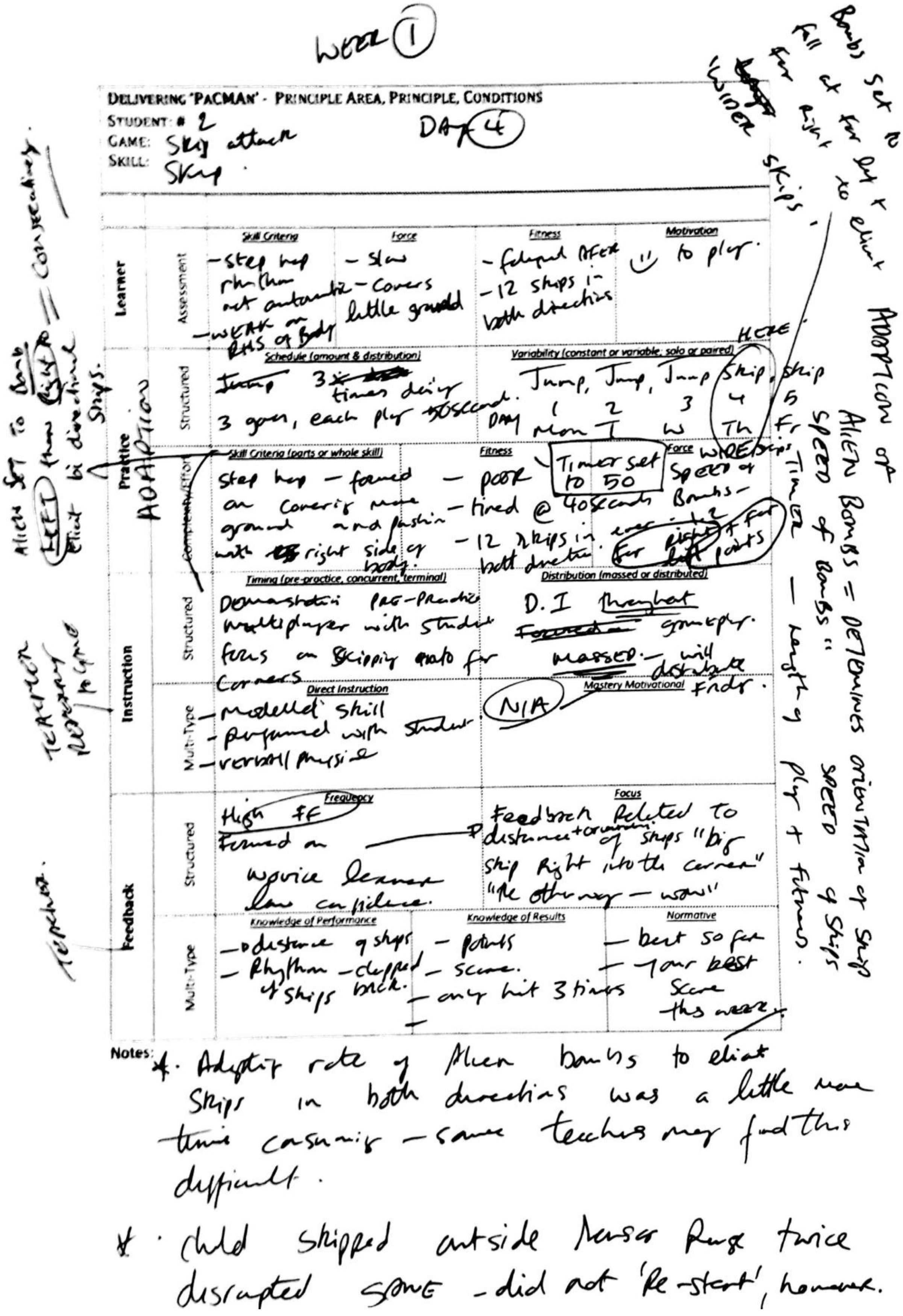
Knowledge of Results
- 20 seconds with foot off the ground.
- shape
- foot position
- score
- Dip point (to score).

Normative
N/A.

Notes:

* gameplay pushes the child to improve muscle tone + hop shape – child less willing to participate in this game as it is "more painful

SKIP ATTACK



WEEK ①

DELIVERING 'PACMAN' - PRINCIPLE AREA, PRINCIPLE, CONDITIONS

STUDENT: # 2 DAY ④

GAME: Skip attack

SKILL: Skip.

Learner	Assessment	Skill Criteria -step hop rhythm not automatic -WEAK on RHS of Body	Force - slow - covers little ground	Fitness - fatigued after -12 skips in both directions	Motivation ☺ to play.
Practice	Structured	Schedule (amount & distribution) ~~Jump~~ 3 times daily 3 goes, each play ~~50~~seconds.		Variability (constant or variable; solo or paired) Jump, Jump, Jump, Skip, Skip DAY 1 2 3 4 5 Mon T W Th Fr HERE	
	Complexity/Effort	Skill Criteria (parts or whole skill) Step hop – formed on covering more ground and faster with right side of body.		Fitness – poor – tired @ 40seconds -12 skips in both directions. Timer set to 50	Force WIDER skips Speed of Bombs – for right + for left parts
Instruction	Structured	Timing (pre-practice, concurrent, terminal) Demonstration pre-practice walkplayer with student focus on skipping into far corners		Distribution (massed or distributed) D.I throughout ~~Focused~~ gameplay. massed. – will distribute fdr.	
	Multi-Type	Direct Instruction -modelled skill -performed with student -verbal/physical		Mastery Motivational N/A	
Feedback	Structured	Frequency High FF focused on novice learner low confidence.		Focus Feedback related to distance + orientation of skips "big skip right into the corner" "the other way – wow"	
	Multi-Type	Knowledge of Performance – distance of skips – Rhythm – clapped back of skips	Knowledge of Results – points – score. – only hit 3 times	Normative – best so far – your best score this week.	

Notes: * Adapting rate of Alien bombs to elicit skips in both directions was a little more time consuming – some teachers may find this difficult.

* child skipped outside sensor range twice disrupted game – did not 'Re-start', however.

Alien set to Bomb LEFT then Right to elicit bi directional skips. = CONSECUTIVELY.

ADAPTATION

TEACHER RECOVERY to GAME

Teacher.

Bombs set to fall at far left + far right to elicit ~~longer~~ WIDER skips.

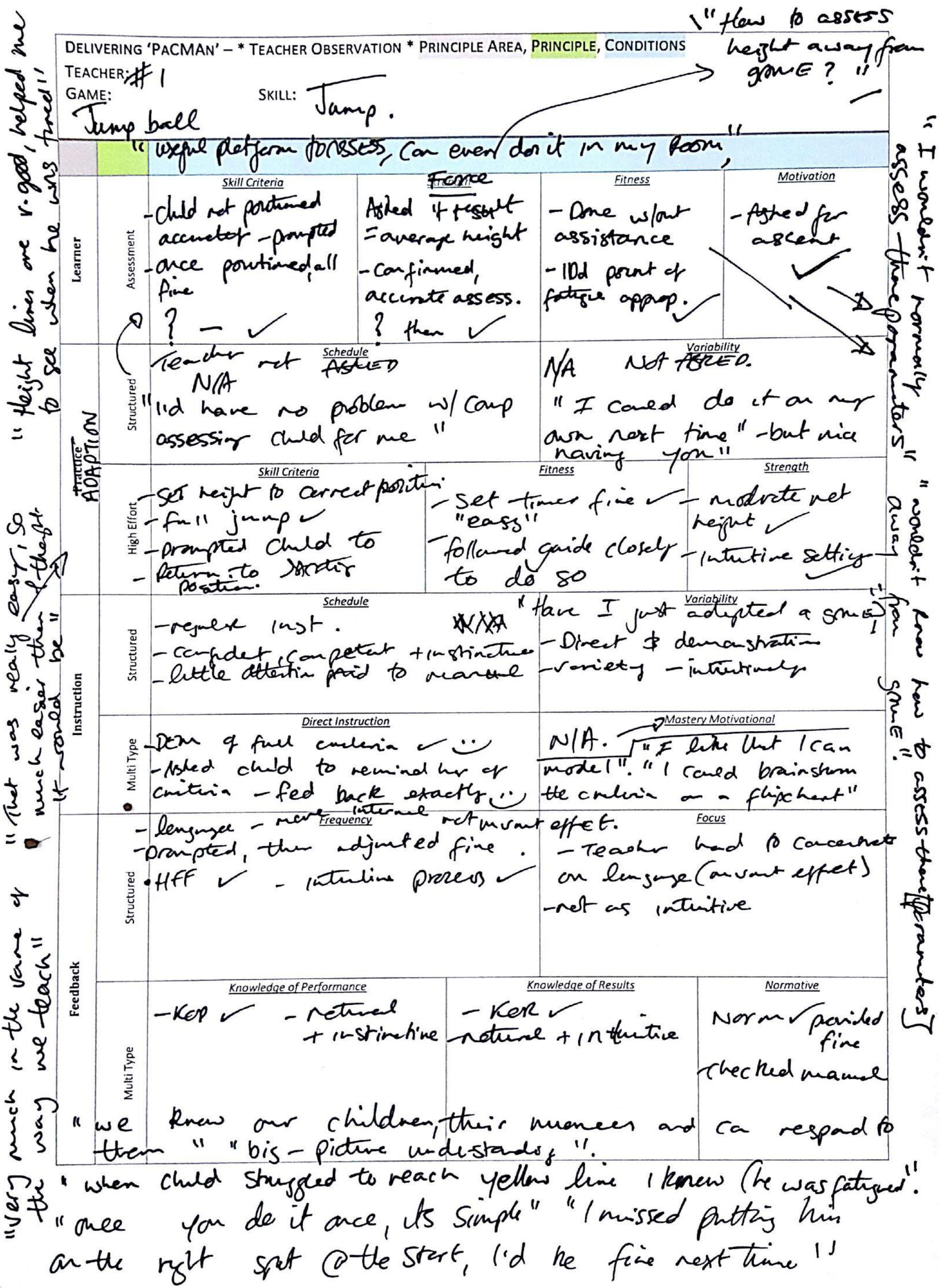
ADAPTATION of ALIEN BOMBS = DETERMINES ORIENTATION of SKIP SPEED of BOMBS = SPEED of SKIPS

TIMER – length of play + fitness.

APPENDIX 2.2

COMPLETED DEPLOYMENT FORMS DETAILING TEACHER EXPERIENCES (EVALUATION 2)

TEACHER #1



DELIVERING 'PACMAN' – * TEACHER OBSERVATION * PRINCIPLE AREA, PRINCIPLE, CONDITIONS

TEACHER: #1

GAME: Jump ball

SKILL: Jump.

"How to assess height away from game?"

" useful platform to assess, can even do it in my room, "

Learner

Assessment

Skill Criteria	~~Strength~~ Force	Fitness	Motivation
-Child not positioned accurately - prompted -once positioned, all fine ? – ✓	Asked if result = average height -Confirmed, accurate assess. ? then ✓	- Done w/out assistance - Id'd point of fatigue approp. ✓	- Asked for ascent ✓

~~Practice~~ ADAPTION

Structured

Schedule	Variability
Teacher not ~~ASKED~~ N/A "I'd have no problem w/ Comp assessing child for me"	N/A Not ~~ASKED~~. " I could do it on my own next time " - but nice having you"

High Effort

Skill Criteria	Fitness	Strength
-Set height to correct position -Full jump ✓ -prompted child to -return to ~~starting~~ position.	-Set timer fine ✓ "easy" -followed guide closely to do 80	- moderate net height ✓ -Intuitive setting

Instruction

Structured

Schedule	Variability
-regular inst. ~~N/A~~ -confident, competent + instinctive -little attention paid to manual	"Have I just adapted a game!" -Direct & demonstration -variety - intentionally

Multi Type

Direct Instruction	Mastery Motivational
-DEM of full criteria ✓ :) -Asked child to remind her of criteria - fed back exactly :)	N/A. "I like that I can model!". "I could brainstorm the criteria on a flipchart"

Feedback

Structured

Frequency	Focus
- language - more internal not invariant effect. -prompted, then adjusted fine. •HFF ✓ - intuitive process ✓	- Teacher had to concentrate on language (invariant effect) -not as intuitive

Multi Type

Knowledge of Performance	Knowledge of Results	Normative
-KoP ✓ - natural + instinctive	- KoR ✓ natural + intuitive	Norm ✓ provided fine checked manual

" we know our children, their nuances and can respond to them " "big-picture understanding".

" when child struggled to reach yellow line I knew (he was fatigued".

" once you do it once, its simple" "I missed putting him on the right spot @ the start, I'd be fine next time"

" Height lines are v. good, helped me to see when he was tired!!"

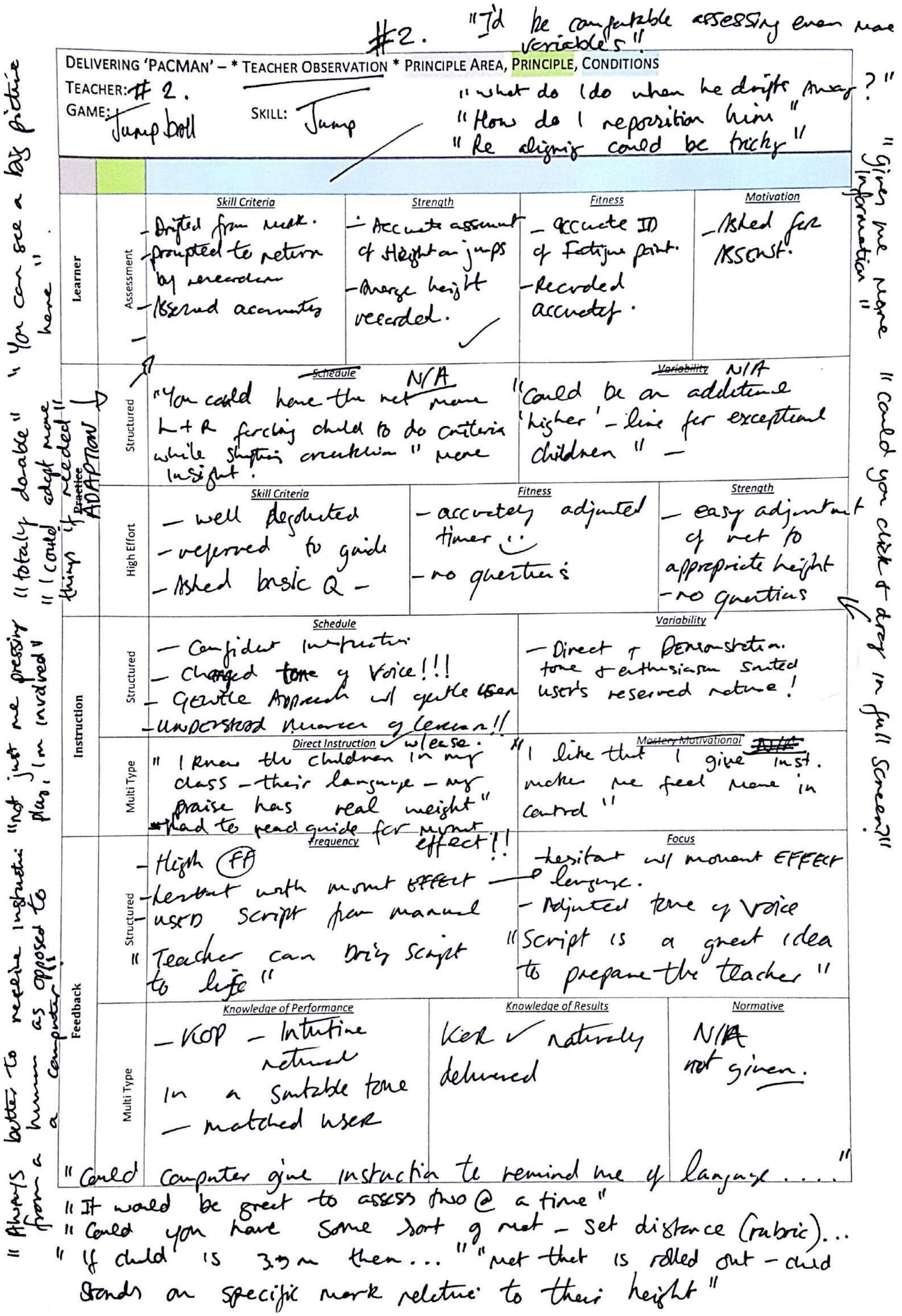
" That was really easy, so much easier than I thought it would be"

"Very much in the vane of the way we teach"

" I wouldn't normally assess these parameters"

" wouldn't know how to assess these [parameters] away from game."

TEACHER #2



#2. "I'd be comfortable assessing even more variables"

DELIVERING 'PACMAN' – * TEACHER OBSERVATION * PRINCIPLE AREA, PRINCIPLE, CONDITIONS

TEACHER: # 2.

GAME: Jump ball

SKILL: Jump

"what do I do when he drifts away?"
"How do I reposition him"
"Re aligning could be tricky"

Learner	Assessment	Skill Criteria - Drifted from mark. - prompted to return by screen - Assessed accurately -	Strength - Accurate assessment of Height on jumps - Average height recorded. ✓	Fitness - accurate ID of Fatigue point. - Recorded accurately.	Motivation - Asked for ASSIST.
~~Practice~~ ADAPTATION	Structured	~~Schedule~~ N/A "You could have the net move L + R forcing child to do criteria while shifting orientation" more insight.	~~Variability~~ N/A "Could be an additional 'higher' - line for exceptional children" –		
	High Effort	Skill Criteria - well deducted - referred to guide - Asked basic Q –	Fitness - accurately adjusted timer :) - no questions	Strength - easy adjustment of net to appropriate height - no questions	
Instruction	Structured	Schedule - Confident instruction - Changed ~~tone~~ of Voice!!! - Gentle Approach w/ gentle user - UNDERSTOOD nuances of lesson!!	Variability - Direct & Demonstration. tone & enthusiasm suited user's reserved nature!		
	Multi Type	Direct Instruction ✓ w/ ease. "I knew the children in my class – their language – my praise has real weight" *had to read guide for moment effect!!	~~Mastery Motivational~~ ~~N/A~~ "I like that I give inst. makes me feel more in control"		
Feedback	Structured	Frequency - High (FF) - hesitant with moment EFFECT - USED Script from manual "Teacher can bring script to life"	Focus - hesitant w/ moment EFFECT language. - Adjusted tone of voice "Script is a great idea to prepare the teacher"		
	Multi Type	Knowledge of Performance - KOP – Intuitive natural in a suitable tone - matched USER	Knowledge of Results KOR ✓ naturally delivered	Normative N/A not given.	

"Could computer give instruction to remind me of language...."
"It would be great to assess two @ a time"
"Could you have some sort of mat – set distance (rubric)...
"If child is 3.5m then..." "mat that is rolled out – child stands on specific mark relative to their height"

"You can see a big picture here"

"totally doable"

"I could adapt more things if needed"

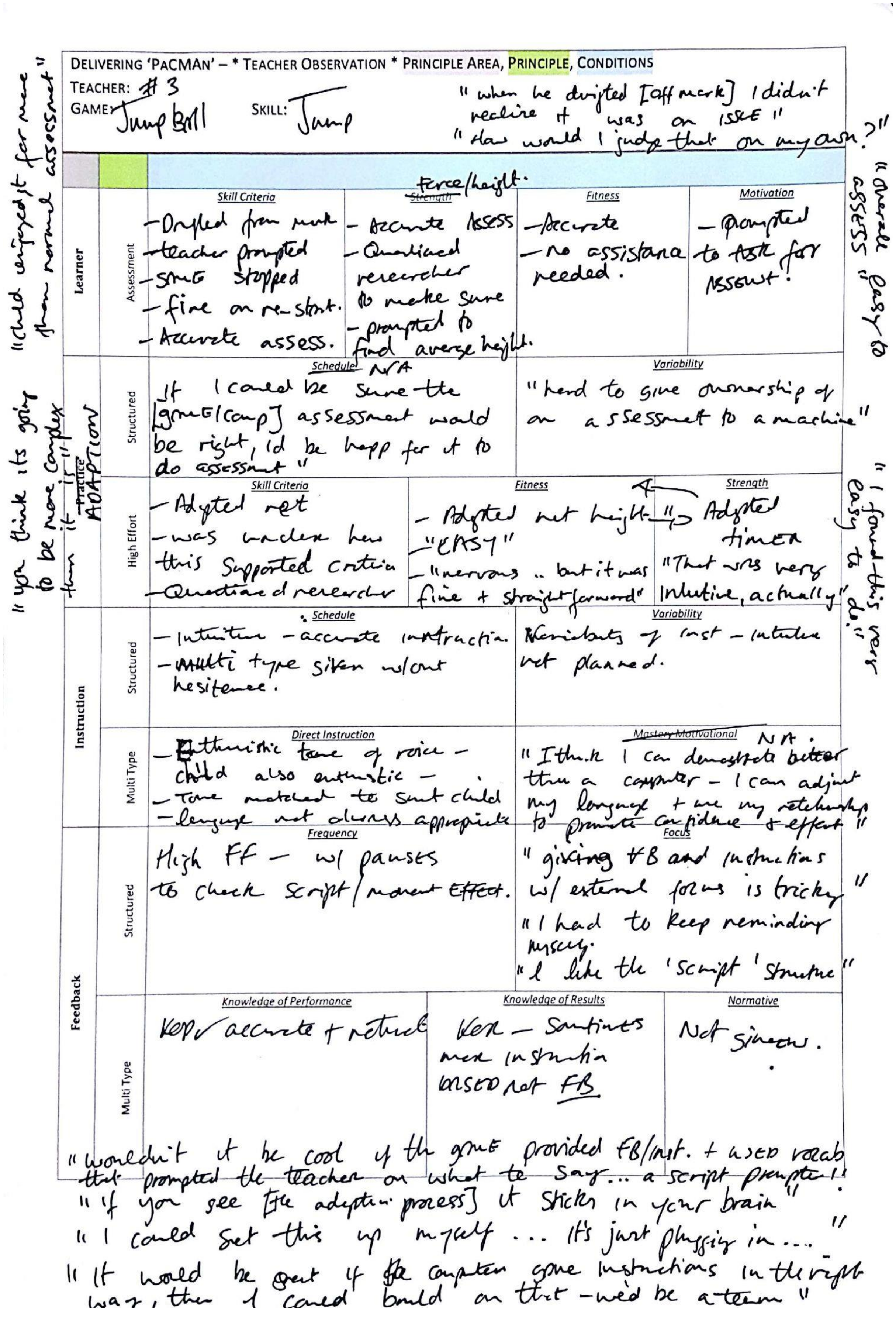
"not just me pressing play, I'm involved"

"Always better to receive instruction from a human as opposed to a computer!!"

"Given me more information"

"Could you click & drag in full screen?"

TEACHER #3



DELIVERING 'PACMAN' – * TEACHER OBSERVATION * PRINCIPLE AREA, PRINCIPLE, CONDITIONS

TEACHER: #3

GAME: Jump Ball

SKILL: Jump

"when he drifted [off mark] I didn't realise it was an ISSUE"

"How would I judge that on my own?"

Learner	Assessment	Skill Criteria	-Drifted from mark -teacher prompted -game stopped -fine on re-start. -Accurate assess.
		~~Strength~~ Force/height.	- Accurate ASSESS -Questioned researcher to make sure -prompted to find average height.
		Fitness	-Accurate -no assistance needed.
		Motivation	-prompted to ASK for ASSESSMENT!
~~Practice~~ ADAPTION	Structured	Schedule N/A	If I could be sure the [game/comp] assessment would be right, I'd be happy for it to do assessment"
		Variability	"hard to give ownership of an assessment to a machine"
	High Effort	Skill Criteria	-Adapted net -was unclear how this supported criteria -Questioned researcher
		Fitness	- Adapted net height -"EASY" -"nervous .. but it was fine + straightforward"
		Strength	Adapted timer "That was very intuitive, actually"
Instruction	Structured	Schedule	-Intuitive -accurate instruction. -multi type given w/out hesitance.
		Variability	Variability of inst - intuitive not planned.
	Multi Type	Direct Instruction	-Enthusiastic tone of voice - child also enthusiastic - -Tone matched to suit child -language not always appropriate
		~~Mastery Motivational~~ N/A.	"I think I can demonstrate better than a computer - I can adjust my language + use my relationship to promote confidence & effort"
Feedback	Structured	Frequency	High FF - w/ pauses to check script/movement Effect.
		Focus	"giving FB and instructions w/ external focus is tricky" "I had to keep reminding myself. "I like the 'script' structure"
	Multi Type	Knowledge of Performance	KP ✓ accurate + natural
		Knowledge of Results	KR – sometimes more instruction based not FB
		Normative	Not sincere.

"child enjoyed it for more than normal assessment"

"you think its going to be more complex than it is"

"Overall ASSESS 'easy to'"

"I found this very easy to do."

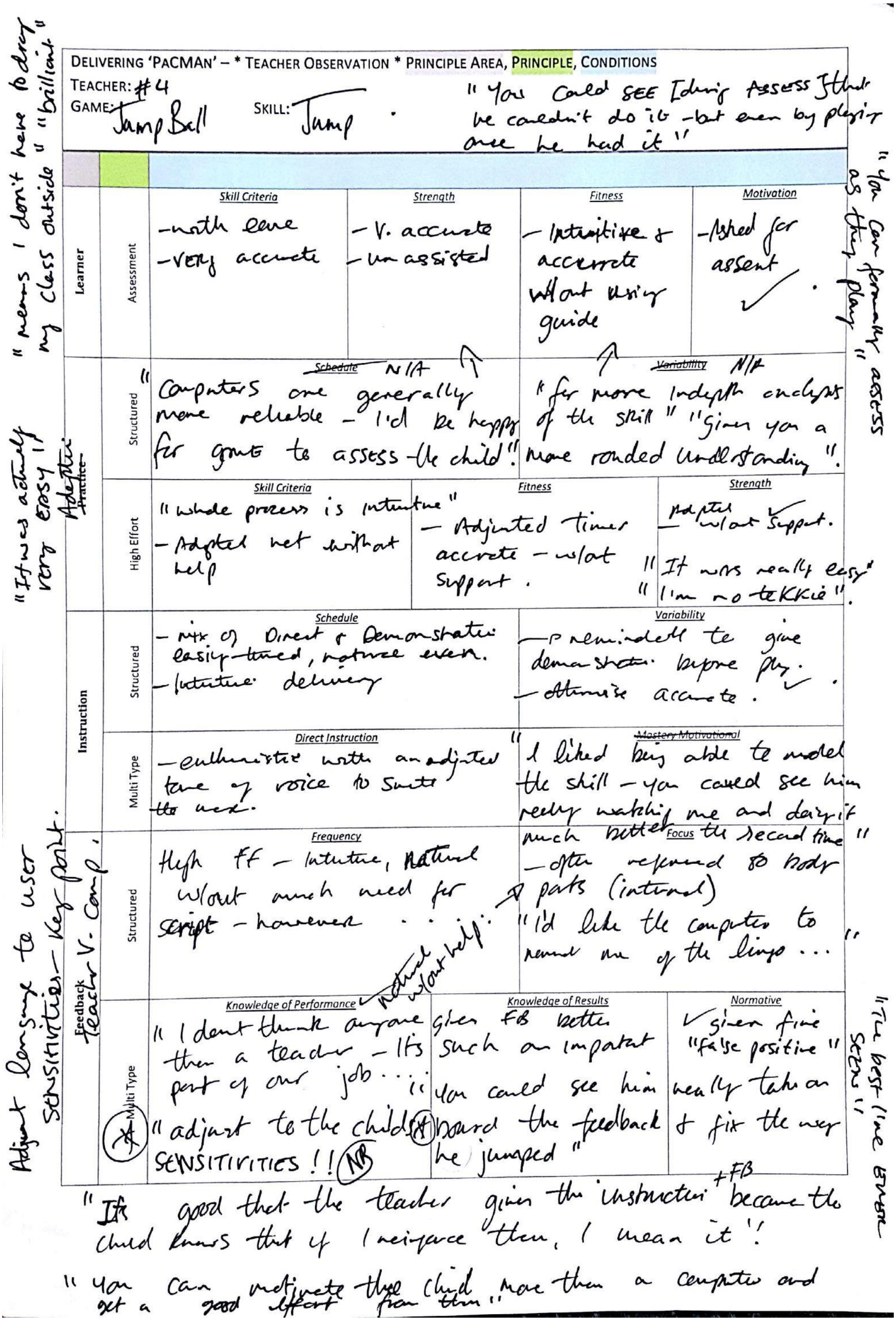
"wouldn't it be cool if the game provided FB/inst. + used vocab that prompted the teacher on what to say... a script prompter!"

"If you see [the adaption process] it sticks in your brain".

"I could set this up myself ... It's just plugging in ...."

"It would be great if the computer gave instructions in the right way, then I could build on that - we'd be a team"

TEACHER #4



"means I don't have to drag my class outside" "brilliant"

DELIVERING 'PACMAN' – * TEACHER OBSERVATION * PRINCIPLE AREA, PRINCIPLE, CONDITIONS
TEACHER: #4
GAME: Jump Ball
SKILL: Jump

"You could see [doing assess] that he couldn't do it – but even by playing once he had it"

Learner	Assessment	*Skill Criteria* -with ease -very accurate	*Strength* -V. accurate -un assisted	*Fitness* -Intuitive & accurate w/out using guide	*Motivation* -Asked for assent ✓
Adaptive ~~Practice~~	Structured	*~~Schedule~~* N/A "Computers are generally more reliable – I'd be happy for games to assess the child".		*~~Variability~~* N/A "for more indepth analysis of the skill" "Gives you a more rounded understanding".	
	High Effort	*Skill Criteria* "whole process is intuitive" -Adapted net without help	*Fitness* -Adjusted timer accurate – w/out support.	*Strength* -adapted w/out support. ✓ "It was really easy" "I'm no tekkie".	
Instruction	Structured	*Schedule* -mix of Direct & Demonstration easily-timed, natural even. -Intuitive delivery		*Variability* -reminded to give demonstration before play. ✓ -otherwise accurate.	
	Multi Type	*Direct Instruction* -enthusiastic with an adjusted tone of voice to suit ~~the user~~.		*~~Mastery Motivational~~* "I liked being able to model the skill – you could see him really watching me and doing it much better the second time"	
Feedback Teacher V. Comp.	Structured	*Frequency* High FF – Intuitive, natural w/out much need for script – however . . . natural w/out help.		*Focus* -often referred to body parts (internal) "I'd like the computer to remind me of the lingo ..."	
	Multi Type	*Knowledge of Performance* "I dont think anyone than a teacher – It's part of our job ...." Ⓧ "adjust to the child's SENSITIVITIES!! NB	*Knowledge of Results* gives FB better such an important "You could see him Ⓧ board the feedback he jumped"	*Normative* ✓ given fine "false positive" really take on & fix the way	

"It was actually very easy!!"

Adjust language to user SENSITIVITIES – Key point.

"You can formally assess as they play"

"The best line ever seen!!"

"It's good that the teacher gives the instruction +FB because the child knows that if I reinforce them, I mean it"!

"You can motivate the child more than a computer and get a good effort from ~~them~~."

APPENDIX 3

SCHEDULE, VARIABILITY AND LOGISTICAL CONSIDERATION FOR DEPLOYMENT OF VIDEO GAMES IN THE CLASSROOM OVER AN EIGHT WEEK PERIOD

SCHEDULE AND VARIABILITY OF GAMEPLAY

Time	JUMP: Jump Ball	HOP: Hop Ball	SKIP: Skip Attack	SLIDE: Slide Ball
Week 1	session 1,2, 3 ✓	session 4,5 ✓		
Week 2			session 1,2, 3 ✓	session 4,5 ✓
Week 3	session 1,2 ✓	session 3,4,5 ✓		
Week 4			session 1,2 ✓	session 3,4,5 ✓
Week 5	session 1,2, 3 ✓	session 4,5 ✓		
Week 6			session 1,2, 3 ✓	session 4,5 ✓
Week 7	session 1,2 ✓	session 3,4,5 ✓		
Week 8			session 1,2 ✓	session 3,4,5 ✓

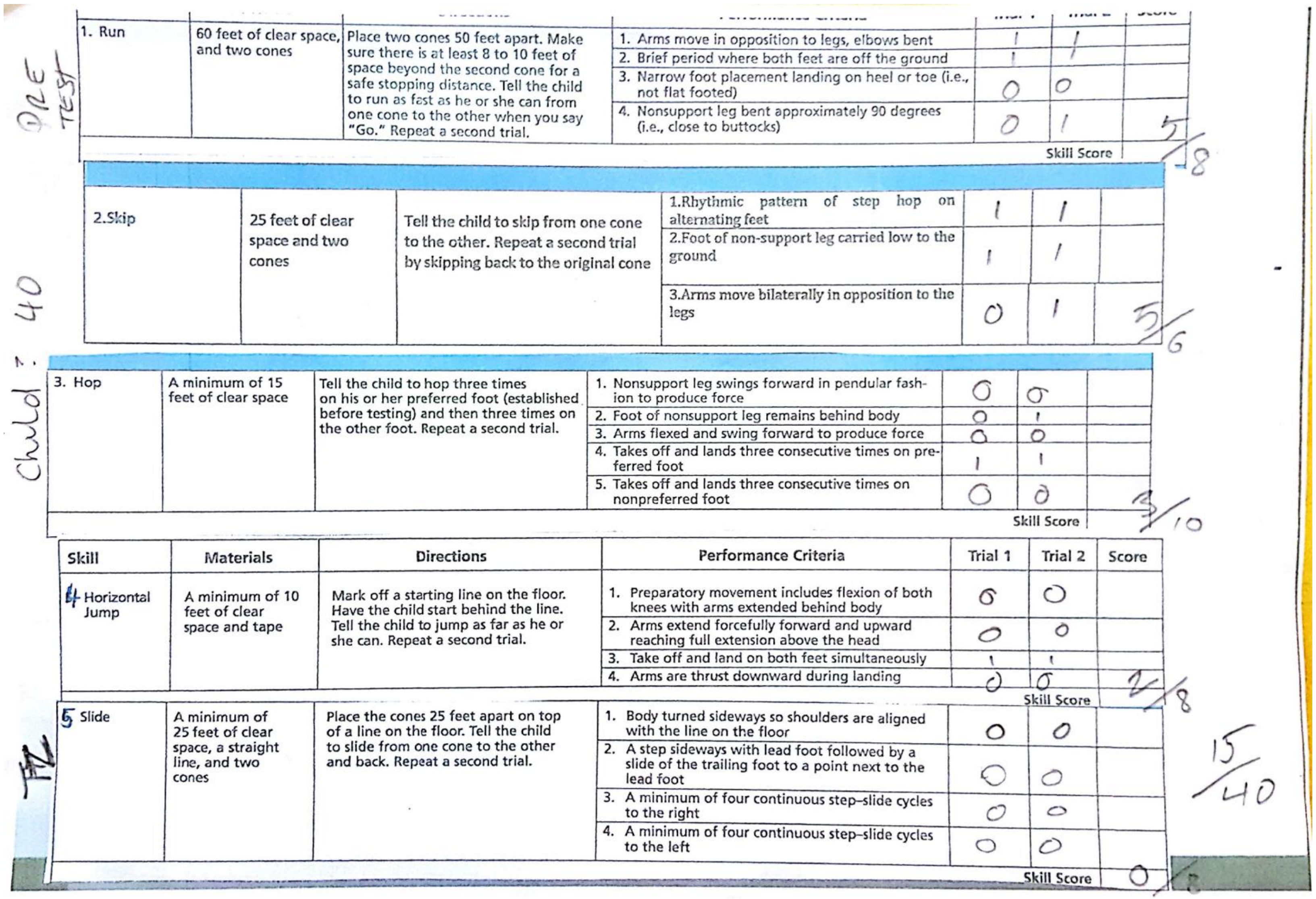
*Session 1 = Monday, 2 = Tuesday, 3 = Wednesday, 4 = Thursday, 5 = Friday

- Gameplay in this study integrated into the school day as part of daily ‘station activities’.
- Each class of 24 divided into 4 groups of 6 children
- Whilst one group played video games for locomotor acquisition, three other groups worked on a variety of other curricular activities
- Groups rotated every 12-15 minutes
- Schedule and variability of skill practice in-line with PaCMAn

APPENDIX 4

SAMPLE TGMD-2 SCORE SHEETS FOR THREE CHILDREN: PRETEST, INTERIM TEST AND POSTTEST

CHILD 40. PRETEST



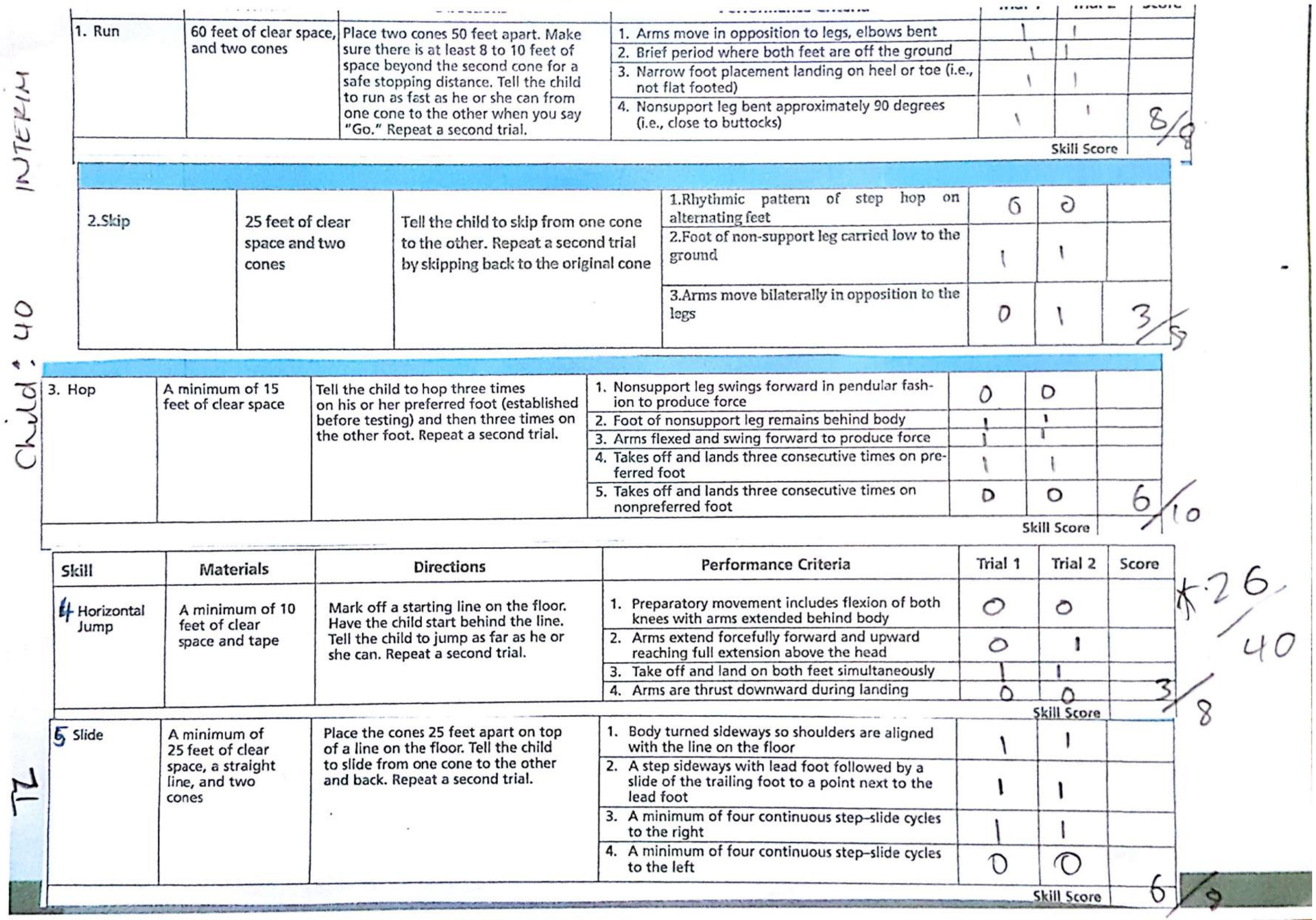
PRE TEST

Child : 40

1. Run	60 feet of clear space, and two cones	Place two cones 50 feet apart. Make sure there is at least 8 to 10 feet of space beyond the second cone for a safe stopping distance. Tell the child to run as fast as he or she can from one cone to the other when you say "Go." Repeat a second trial.	1. Arms move in opposition to legs, elbows bent	1	1	
			2. Brief period where both feet are off the ground	1	1	
			3. Narrow foot placement landing on heel or toe (i.e., not flat footed)	0	0	
			4. Nonsupport leg bent approximately 90 degrees (i.e., close to buttocks)	0	1	
					Skill Score	5/8
2.Skip	25 feet of clear space and two cones	Tell the child to skip from one cone to the other. Repeat a second trial by skipping back to the original cone	1.Rhythmic pattern of step hop on alternating feet	1	1	
			2.Foot of non-support leg carried low to the ground	1	1	
			3.Arms move bilaterally in opposition to the legs	0	1	5/6
3. Hop	A minimum of 15 feet of clear space	Tell the child to hop three times on his or her preferred foot (established before testing) and then three times on the other foot. Repeat a second trial.	1. Nonsupport leg swings forward in pendular fashion to produce force	0	0	
			2. Foot of nonsupport leg remains behind body	0	1	
			3. Arms flexed and swing forward to produce force	0	0	
			4. Takes off and lands three consecutive times on preferred foot	1	1	
			5. Takes off and lands three consecutive times on nonpreferred foot	0	0	
					Skill Score	3/10
Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
4 Horizontal Jump	A minimum of 10 feet of clear space and tape	Mark off a starting line on the floor. Have the child start behind the line. Tell the child to jump as far as he or she can. Repeat a second trial.	1. Preparatory movement includes flexion of both knees with arms extended behind body	0	0	
			2. Arms extend forcefully forward and upward reaching full extension above the head	0	0	
			3. Take off and land on both feet simultaneously	1	1	
			4. Arms are thrust downward during landing	0	0	
					Skill Score	2/8
5 Slide	A minimum of 25 feet of clear space, a straight line, and two cones	Place the cones 25 feet apart on top of a line on the floor. Tell the child to slide from one cone to the other and back. Repeat a second trial.	1. Body turned sideways so shoulders are aligned with the line on the floor	0	0	
			2. A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot	0	0	
			3. A minimum of four continuous step–slide cycles to the right	0	0	
			4. A minimum of four continuous step–slide cycles to the left	0	0	
					Skill Score	0/8

15/40

CHILD 40. INTERIM TEST



INTERIM

Child : 40

T2

*26 / 40

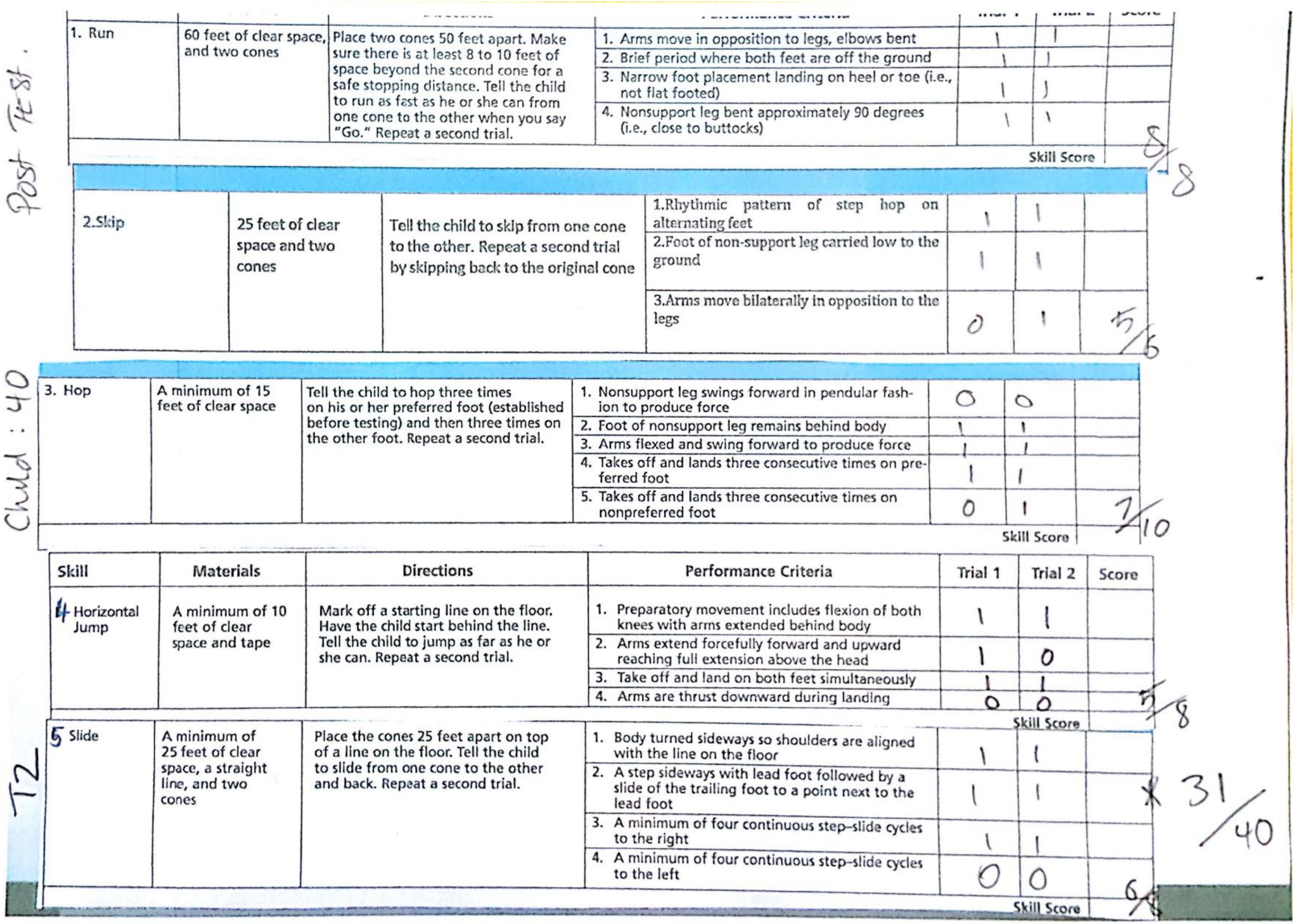
1. Run	60 feet of clear space, and two cones	Place two cones 50 feet apart. Make sure there is at least 8 to 10 feet of space beyond the second cone for a safe stopping distance. Tell the child to run as fast as he or she can from one cone to the other when you say "Go." Repeat a second trial.	1. Arms move in opposition to legs, elbows bent	1	1	
			2. Brief period where both feet are off the ground	1	1	
			3. Narrow foot placement landing on heel or toe (i.e., not flat footed)	1	1	
			4. Nonsupport leg bent approximately 90 degrees (i.e., close to buttocks)	1	1	8/8
					Skill Score	

2.Skip	25 feet of clear space and two cones	Tell the child to skip from one cone to the other. Repeat a second trial by skipping back to the original cone	1.Rhythmic pattern of step hop on alternating feet	0	0	
			2.Foot of non-support leg carried low to the ground	1	1	
			3.Arms move bilaterally in opposition to the legs	0	1	3/5

3. Hop	A minimum of 15 feet of clear space	Tell the child to hop three times on his or her preferred foot (established before testing) and then three times on the other foot. Repeat a second trial.	1. Nonsupport leg swings forward in pendular fashion to produce force	0	0	
			2. Foot of nonsupport leg remains behind body	1	1	
			3. Arms flexed and swing forward to produce force	1	1	
			4. Takes off and lands three consecutive times on preferred foot	1	1	
			5. Takes off and lands three consecutive times on nonpreferred foot	0	0	6/10
					Skill Score	

Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
4 Horizontal Jump	A minimum of 10 feet of clear space and tape	Mark off a starting line on the floor. Have the child start behind the line. Tell the child to jump as far as he or she can. Repeat a second trial.	1. Preparatory movement includes flexion of both knees with arms extended behind body	0	0	
			2. Arms extend forcefully forward and upward reaching full extension above the head	0	1	
			3. Take off and land on both feet simultaneously	1	1	
			4. Arms are thrust downward during landing	0	0	3/8
					Skill Score	
5 Slide	A minimum of 25 feet of clear space, a straight line, and two cones	Place the cones 25 feet apart on top of a line on the floor. Tell the child to slide from one cone to the other and back. Repeat a second trial.	1. Body turned sideways so shoulders are aligned with the line on the floor	1	1	
			2. A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot	1	1	
			3. A minimum of four continuous step-slide cycles to the right	1	1	
			4. A minimum of four continuous step-slide cycles to the left	0	0	
					Skill Score	6/8

CHILD 40. POSTTEST



Post Test.

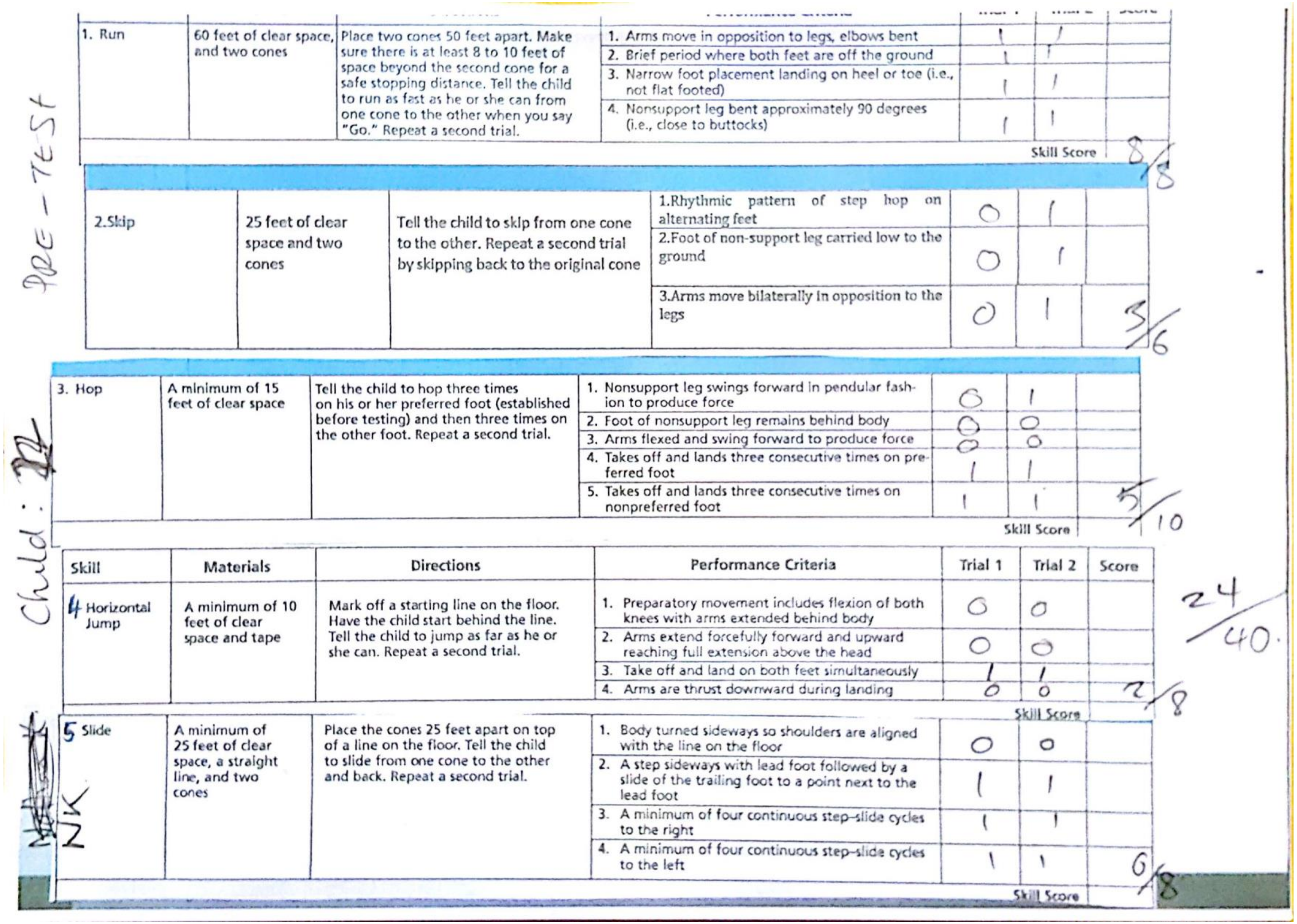
Child : 40

T2

Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
1. Run	60 feet of clear space, and two cones	Place two cones 50 feet apart. Make sure there is at least 8 to 10 feet of space beyond the second cone for a safe stopping distance. Tell the child to run as fast as he or she can from one cone to the other when you say "Go." Repeat a second trial.	1. Arms move in opposition to legs, elbows bent	1	1	
			2. Brief period where both feet are off the ground	1	1	
			3. Narrow foot placement landing on heel or toe (i.e., not flat footed)	1	1	
			4. Nonsupport leg bent approximately 90 degrees (i.e., close to buttocks)	1	1	
					Skill Score	8/8
2.Skip	25 feet of clear space and two cones	Tell the child to skip from one cone to the other. Repeat a second trial by skipping back to the original cone	1.Rhythmic pattern of step hop on alternating feet	1	1	
			2.Foot of non-support leg carried low to the ground	1	1	
			3.Arms move bilaterally in opposition to the legs	0	1	5/6
3. Hop	A minimum of 15 feet of clear space	Tell the child to hop three times on his or her preferred foot (established before testing) and then three times on the other foot. Repeat a second trial.	1. Nonsupport leg swings forward in pendular fashion to produce force	0	0	
			2. Foot of nonsupport leg remains behind body	1	1	
			3. Arms flexed and swing forward to produce force	1	1	
			4. Takes off and lands three consecutive times on preferred foot	1	1	
			5. Takes off and lands three consecutive times on nonpreferred foot	0	1	
					Skill Score	7/10
4 Horizontal Jump	A minimum of 10 feet of clear space and tape	Mark off a starting line on the floor. Have the child start behind the line. Tell the child to jump as far as he or she can. Repeat a second trial.	1. Preparatory movement includes flexion of both knees with arms extended behind body	1	1	
			2. Arms extend forcefully forward and upward reaching full extension above the head	1	0	
			3. Take off and land on both feet simultaneously	1	1	
			4. Arms are thrust downward during landing	0	0	5/8
					Skill Score	
5 Slide	A minimum of 25 feet of clear space, a straight line, and two cones	Place the cones 25 feet apart on top of a line on the floor. Tell the child to slide from one cone to the other and back. Repeat a second trial.	1. Body turned sideways so shoulders are aligned with the line on the floor	1	1	
			2. A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot	1	1	
			3. A minimum of four continuous step–slide cycles to the right	1	1	
			4. A minimum of four continuous step–slide cycles to the left	0	0	6/8
					Skill Score	

31/40

CHILD 22. PRETEST



Pre-Test

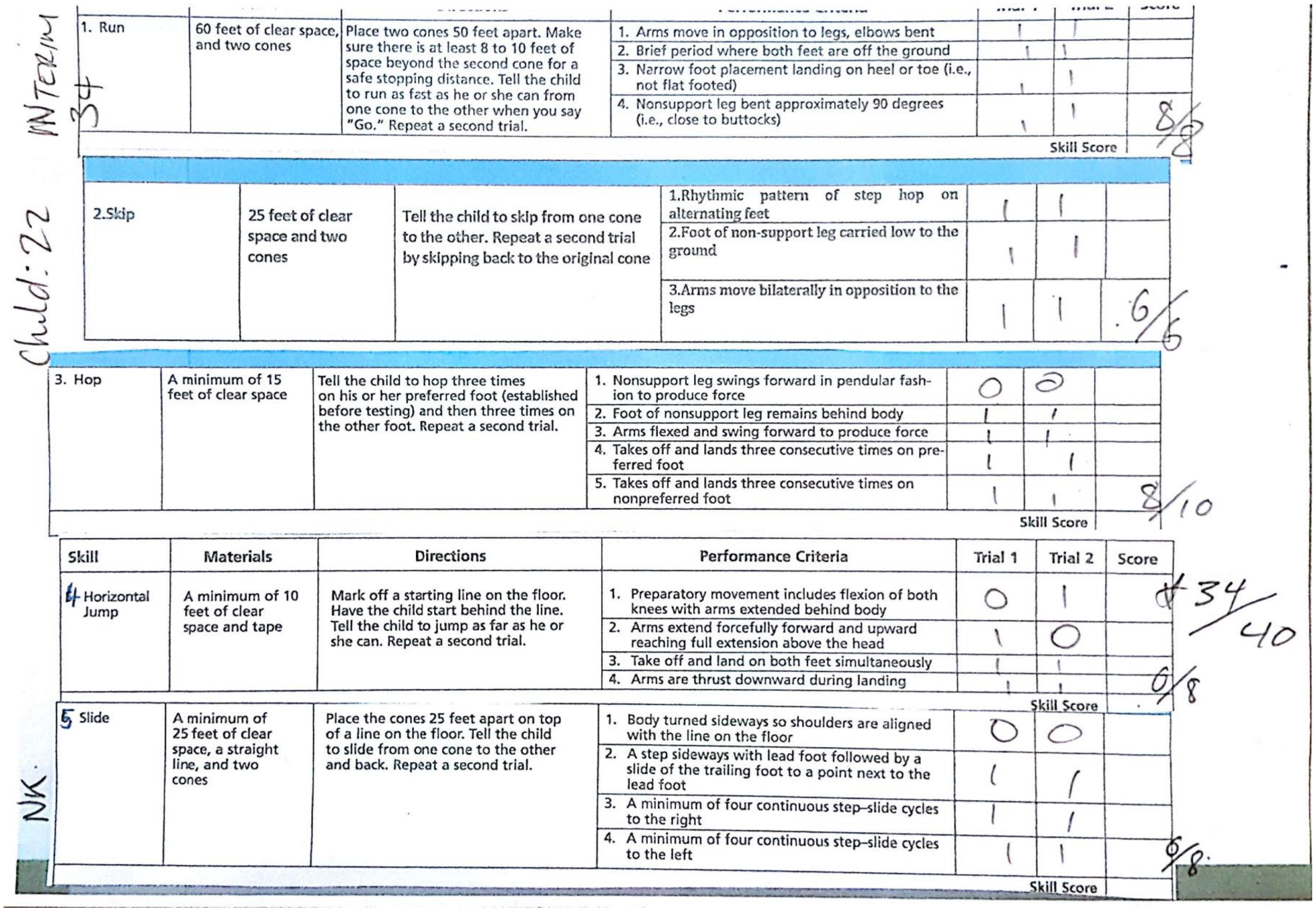
Child : 22

Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
1. Run	60 feet of clear space, and two cones	Place two cones 50 feet apart. Make sure there is at least 8 to 10 feet of space beyond the second cone for a safe stopping distance. Tell the child to run as fast as he or she can from one cone to the other when you say "Go." Repeat a second trial.	1. Arms move in opposition to legs, elbows bent	1	1	
			2. Brief period where both feet are off the ground	1	1	
			3. Narrow foot placement landing on heel or toe (i.e., not flat footed)	1	1	
			4. Nonsupport leg bent approximately 90 degrees (i.e., close to buttocks)	1	1	
					Skill Score	8/8
2.Skip	25 feet of clear space and two cones	Tell the child to skip from one cone to the other. Repeat a second trial by skipping back to the original cone	1.Rhythmic pattern of step hop on alternating feet	0	1	
			2.Foot of non-support leg carried low to the ground	0	1	
			3.Arms move bilaterally in opposition to the legs	0	1	3/6
3. Hop	A minimum of 15 feet of clear space	Tell the child to hop three times on his or her preferred foot (established before testing) and then three times on the other foot. Repeat a second trial.	1. Nonsupport leg swings forward in pendular fashion to produce force	0	1	
			2. Foot of nonsupport leg remains behind body	0	0	
			3. Arms flexed and swing forward to produce force	0	0	
			4. Takes off and lands three consecutive times on preferred foot	1	1	
			5. Takes off and lands three consecutive times on nonpreferred foot	1	1	
					Skill Score	5/10
Skill	**Materials**	**Directions**	**Performance Criteria**	**Trial 1**	**Trial 2**	**Score**
4 Horizontal Jump	A minimum of 10 feet of clear space and tape	Mark off a starting line on the floor. Have the child start behind the line. Tell the child to jump as far as he or she can. Repeat a second trial.	1. Preparatory movement includes flexion of both knees with arms extended behind body	0	0	
			2. Arms extend forcefully forward and upward reaching full extension above the head	0	0	
			3. Take off and land on both feet simultaneously	1	1	
			4. Arms are thrust downward during landing	0	0	2/8
					Skill Score	
5 Slide	A minimum of 25 feet of clear space, a straight line, and two cones	Place the cones 25 feet apart on top of a line on the floor. Tell the child to slide from one cone to the other and back. Repeat a second trial.	1. Body turned sideways so shoulders are aligned with the line on the floor	0	0	
			2. A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot	1	1	
			3. A minimum of four continuous step-slide cycles to the right	1	1	
			4. A minimum of four continuous step-slide cycles to the left	1	1	6/8
					Skill Score	

24/40.

[redacted] NK

CHILD 22. INTERIM TEST



INTERIM 34

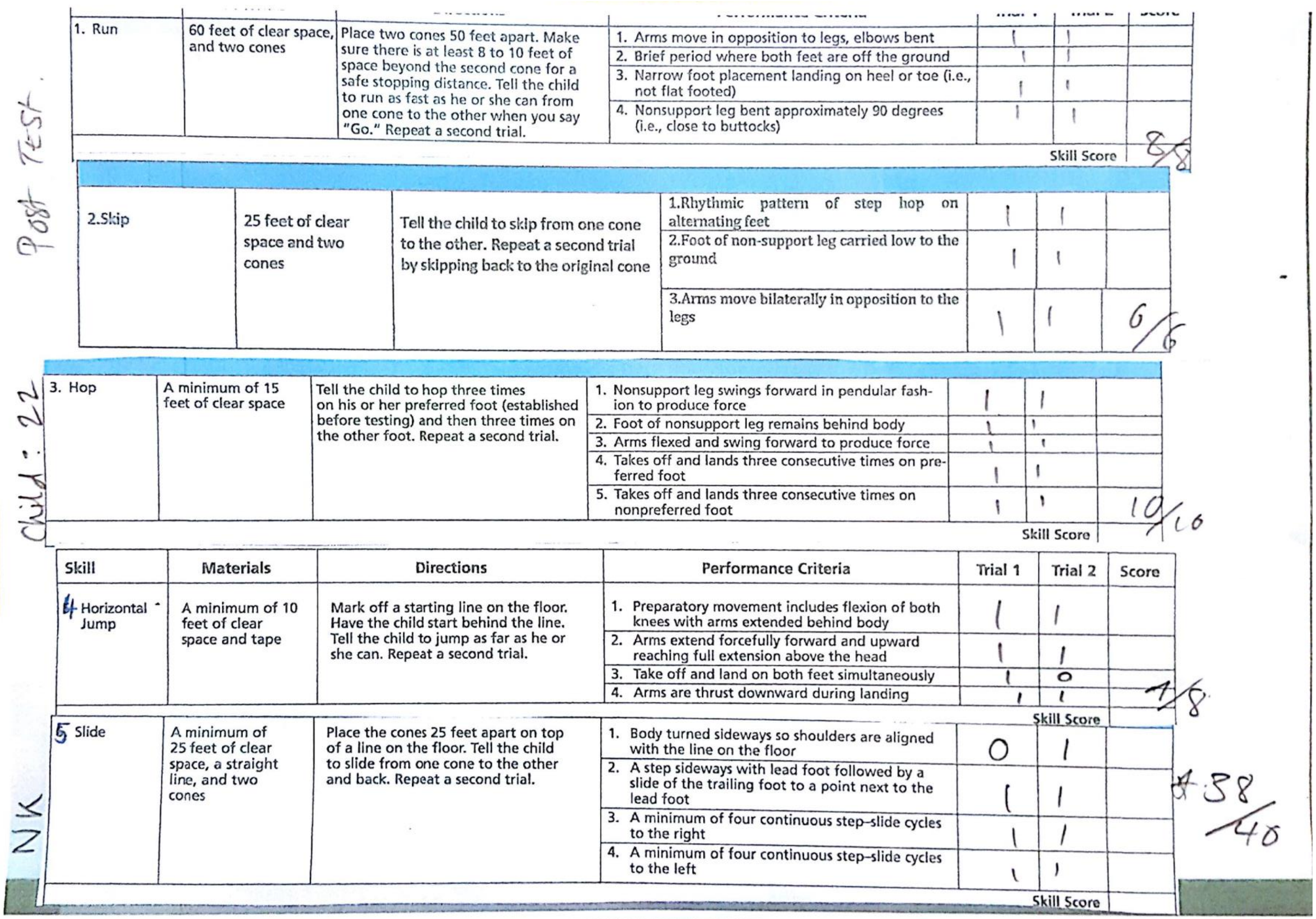
Child: 22

NK.

1. Run	60 feet of clear space, and two cones	Place two cones 50 feet apart. Make sure there is at least 8 to 10 feet of space beyond the second cone for a safe stopping distance. Tell the child to run as fast as he or she can from one cone to the other when you say "Go." Repeat a second trial.	1. Arms move in opposition to legs, elbows bent	1	1	
			2. Brief period where both feet are off the ground	1	1	
			3. Narrow foot placement landing on heel or toe (i.e., not flat footed)	1	1	
			4. Nonsupport leg bent approximately 90 degrees (i.e., close to buttocks)	1	1	8/8
					Skill Score	
2.Skip	25 feet of clear space and two cones	Tell the child to skip from one cone to the other. Repeat a second trial by skipping back to the original cone	1.Rhythmic pattern of step hop on alternating feet	1	1	
			2.Foot of non-support leg carried low to the ground	1	1	
			3.Arms move bilaterally in opposition to the legs	1	1	6/6
3. Hop	A minimum of 15 feet of clear space	Tell the child to hop three times on his or her preferred foot (established before testing) and then three times on the other foot. Repeat a second trial.	1. Nonsupport leg swings forward in pendular fashion to produce force	0	0	
			2. Foot of nonsupport leg remains behind body	1	1	
			3. Arms flexed and swing forward to produce force	1	1	
			4. Takes off and lands three consecutive times on preferred foot	1	1	
			5. Takes off and lands three consecutive times on nonpreferred foot	1	1	8/10
					Skill Score	

Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
4 Horizontal Jump	A minimum of 10 feet of clear space and tape	Mark off a starting line on the floor. Have the child start behind the line. Tell the child to jump as far as he or she can. Repeat a second trial.	1. Preparatory movement includes flexion of both knees with arms extended behind body	0	1	~~4~~ 34/40
			2. Arms extend forcefully forward and upward reaching full extension above the head	1	0	
			3. Take off and land on both feet simultaneously	1	1	
			4. Arms are thrust downward during landing	1	1	6/8
					Skill Score	
5 Slide	A minimum of 25 feet of clear space, a straight line, and two cones	Place the cones 25 feet apart on top of a line on the floor. Tell the child to slide from one cone to the other and back. Repeat a second trial.	1. Body turned sideways so shoulders are aligned with the line on the floor	0	0	
			2. A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot	1	1	
			3. A minimum of four continuous step–slide cycles to the right	1	1	
			4. A minimum of four continuous step–slide cycles to the left	1	1	6/8
					Skill Score	

CHILD 22. POSTTEST



Post Test.

Child : 22

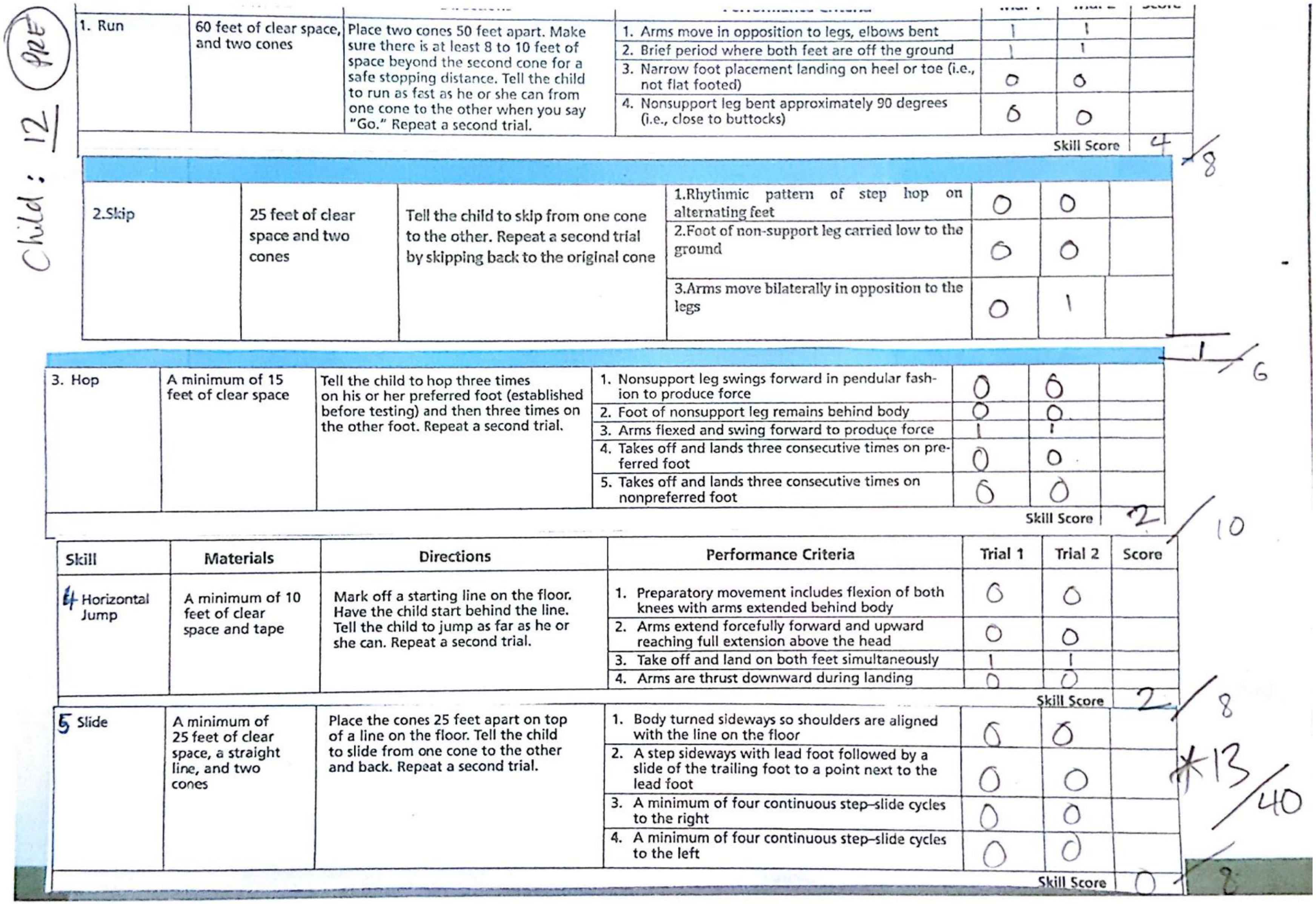
NK

1. Run	60 feet of clear space, and two cones	Place two cones 50 feet apart. Make sure there is at least 8 to 10 feet of space beyond the second cone for a safe stopping distance. Tell the child to run as fast as he or she can from one cone to the other when you say "Go." Repeat a second trial.	1. Arms move in opposition to legs, elbows bent	1	1	
			2. Brief period where both feet are off the ground	1	1	
			3. Narrow foot placement landing on heel or toe (i.e., not flat footed)	1	1	
			4. Nonsupport leg bent approximately 90 degrees (i.e., close to buttocks)	1	1	
					Skill Score	8/8
2.Skip	25 feet of clear space and two cones	Tell the child to skip from one cone to the other. Repeat a second trial by skipping back to the original cone	1.Rhythmic pattern of step hop on alternating feet	1	1	
			2.Foot of non-support leg carried low to the ground	1	1	
			3.Arms move bilaterally in opposition to the legs	1	1	6/6
3. Hop	A minimum of 15 feet of clear space	Tell the child to hop three times on his or her preferred foot (established before testing) and then three times on the other foot. Repeat a second trial.	1. Nonsupport leg swings forward in pendular fashion to produce force	1	1	
			2. Foot of nonsupport leg remains behind body	1	1	
			3. Arms flexed and swing forward to produce force	1	1	
			4. Takes off and lands three consecutive times on preferred foot	1	1	
			5. Takes off and lands three consecutive times on nonpreferred foot	1	1	10/10
					Skill Score	

Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
4 Horizontal Jump	A minimum of 10 feet of clear space and tape	Mark off a starting line on the floor. Have the child start behind the line. Tell the child to jump as far as he or she can. Repeat a second trial.	1. Preparatory movement includes flexion of both knees with arms extended behind body	1	1	
			2. Arms extend forcefully forward and upward reaching full extension above the head	1	1	
			3. Take off and land on both feet simultaneously	1	0	
			4. Arms are thrust downward during landing	1	1	7/8
					Skill Score	
5 Slide	A minimum of 25 feet of clear space, a straight line, and two cones	Place the cones 25 feet apart on top of a line on the floor. Tell the child to slide from one cone to the other and back. Repeat a second trial.	1. Body turned sideways so shoulders are aligned with the line on the floor	0	1	
			2. A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot	1	1	
			3. A minimum of four continuous step-slide cycles to the right	1	1	
			4. A minimum of four continuous step-slide cycles to the left	1	1	
					Skill Score	

#38/40

CHILD 12. PRETEST

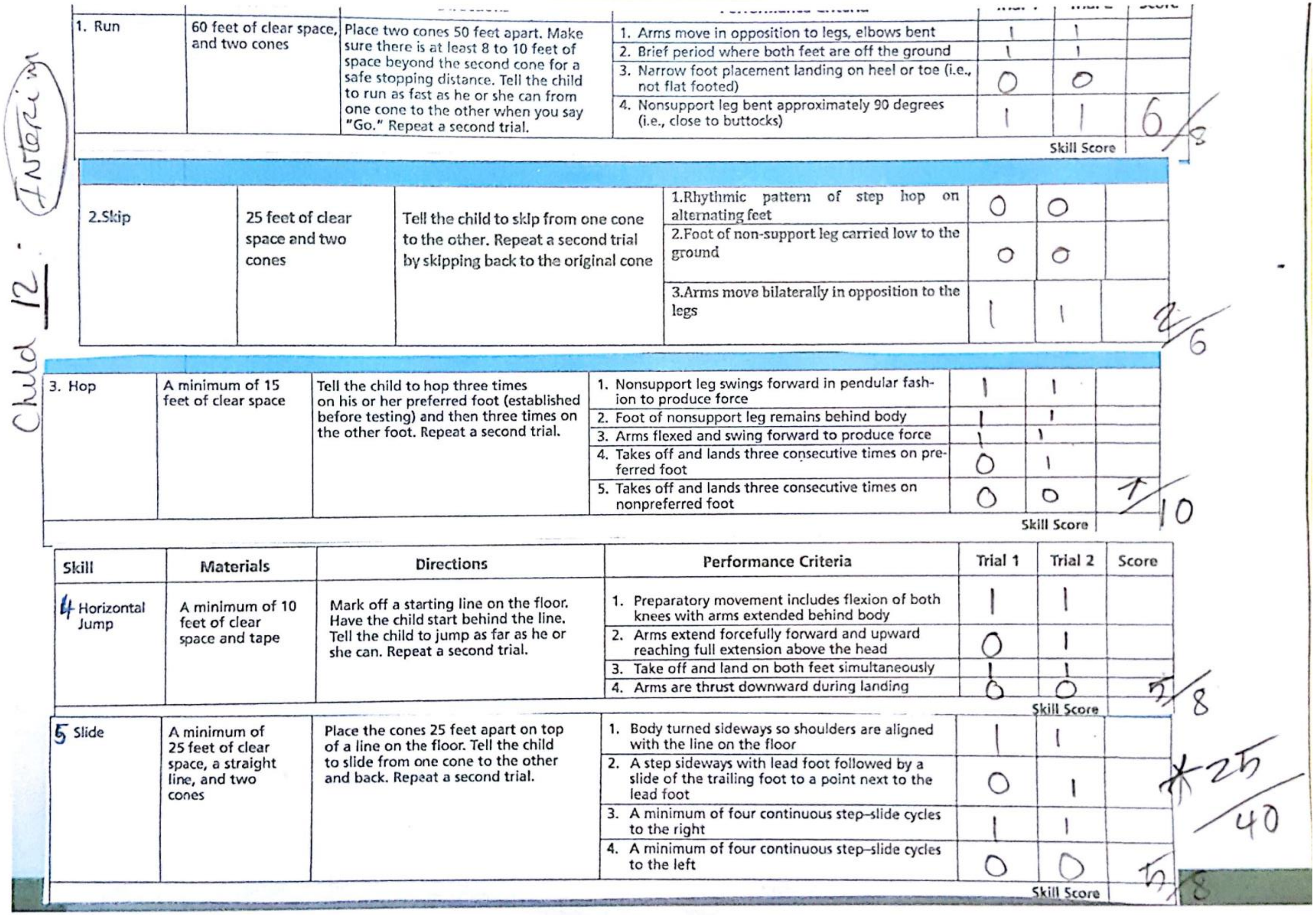


Child : 12 (PRE)

Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
1. Run	60 feet of clear space, and two cones	Place two cones 50 feet apart. Make sure there is at least 8 to 10 feet of space beyond the second cone for a safe stopping distance. Tell the child to run as fast as he or she can from one cone to the other when you say "Go." Repeat a second trial.	1. Arms move in opposition to legs, elbows bent	1	1	
			2. Brief period where both feet are off the ground	1	1	
			3. Narrow foot placement landing on heel or toe (i.e., not flat footed)	0	0	
			4. Nonsupport leg bent approximately 90 degrees (i.e., close to buttocks)	0	0	
					Skill Score	4/8
2.Skip	25 feet of clear space and two cones	Tell the child to skip from one cone to the other. Repeat a second trial by skipping back to the original cone	1.Rhythmic pattern of step hop on alternating feet	0	0	
			2.Foot of non-support leg carried low to the ground	0	0	
			3.Arms move bilaterally in opposition to the legs	0	1	
						1/6
3. Hop	A minimum of 15 feet of clear space	Tell the child to hop three times on his or her preferred foot (established before testing) and then three times on the other foot. Repeat a second trial.	1. Nonsupport leg swings forward in pendular fashion to produce force	0	0	
			2. Foot of nonsupport leg remains behind body	0	0	
			3. Arms flexed and swing forward to produce force	1	1	
			4. Takes off and lands three consecutive times on preferred foot	0	0	
			5. Takes off and lands three consecutive times on nonpreferred foot	0	0	
					Skill Score	2/10
Skill	**Materials**	**Directions**	**Performance Criteria**	**Trial 1**	**Trial 2**	**Score**
4 Horizontal Jump	A minimum of 10 feet of clear space and tape	Mark off a starting line on the floor. Have the child start behind the line. Tell the child to jump as far as he or she can. Repeat a second trial.	1. Preparatory movement includes flexion of both knees with arms extended behind body	0	0	
			2. Arms extend forcefully forward and upward reaching full extension above the head	0	0	
			3. Take off and land on both feet simultaneously	1	1	
			4. Arms are thrust downward during landing	0	0	
					Skill Score	2/8
5 Slide	A minimum of 25 feet of clear space, a straight line, and two cones	Place the cones 25 feet apart on top of a line on the floor. Tell the child to slide from one cone to the other and back. Repeat a second trial.	1. Body turned sideways so shoulders are aligned with the line on the floor	0	0	
			2. A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot	0	0	
			3. A minimum of four continuous step–slide cycles to the right	0	0	
			4. A minimum of four continuous step–slide cycles to the left	0	0	
					Skill Score	0/8

*13/40

CHILD 12. INTERIM TEST

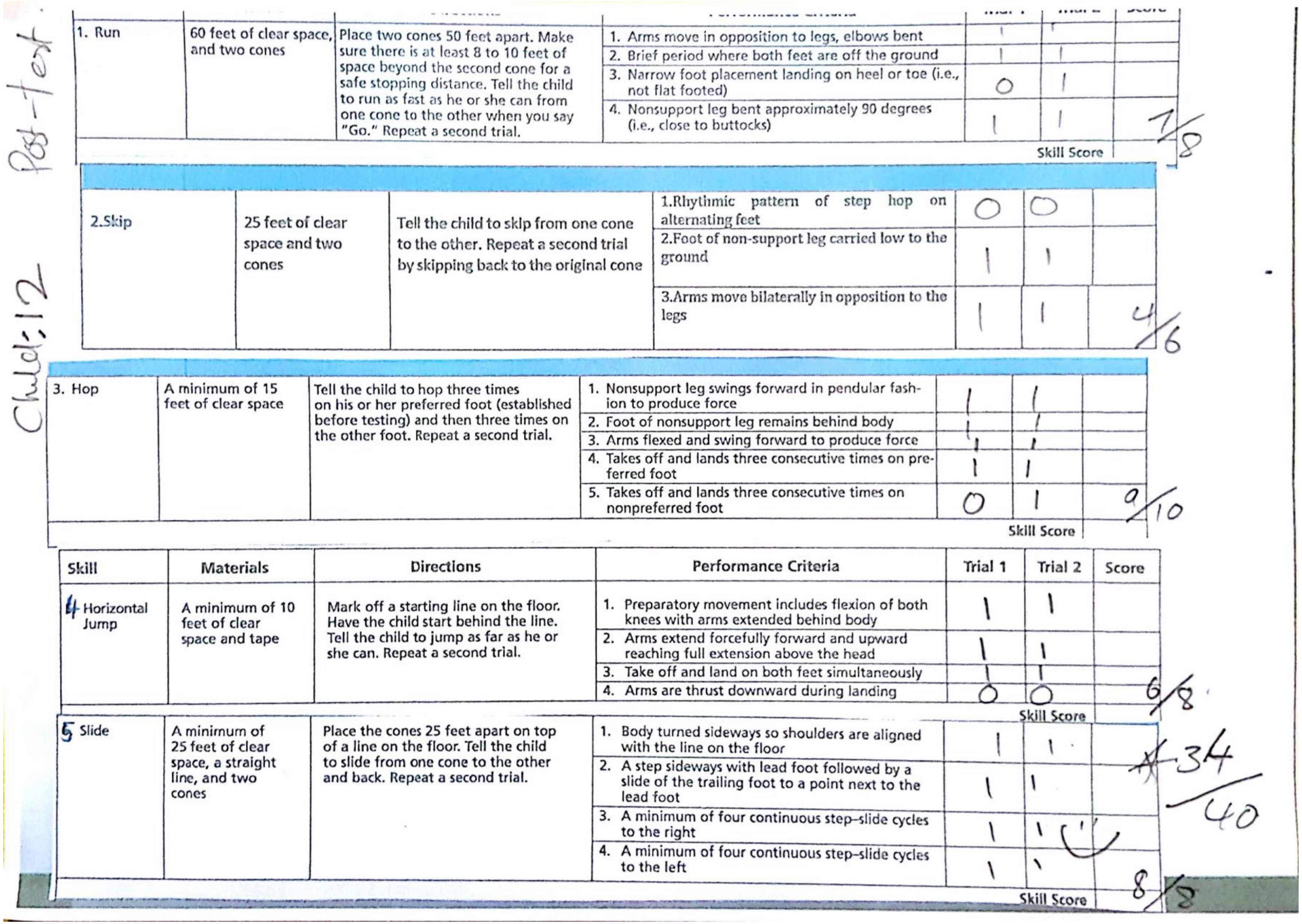


Child 12 . Interim

Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
1. Run	60 feet of clear space, and two cones	Place two cones 50 feet apart. Make sure there is at least 8 to 10 feet of space beyond the second cone for a safe stopping distance. Tell the child to run as fast as he or she can from one cone to the other when you say "Go." Repeat a second trial.	1. Arms move in opposition to legs, elbows bent	1	1	
			2. Brief period where both feet are off the ground	1	1	
			3. Narrow foot placement landing on heel or toe (i.e., not flat footed)	0	0	
			4. Nonsupport leg bent approximately 90 degrees (i.e., close to buttocks)	1	1	
					Skill Score	6/8
2.Skip	25 feet of clear space and two cones	Tell the child to skip from one cone to the other. Repeat a second trial by skipping back to the original cone	1.Rhythmic pattern of step hop on alternating feet	0	0	
			2.Foot of non-support leg carried low to the ground	0	0	
			3.Arms move bilaterally in opposition to the legs	1	1	2/6
3. Hop	A minimum of 15 feet of clear space	Tell the child to hop three times on his or her preferred foot (established before testing) and then three times on the other foot. Repeat a second trial.	1. Nonsupport leg swings forward in pendular fashion to produce force	1	1	
			2. Foot of nonsupport leg remains behind body	1	1	
			3. Arms flexed and swing forward to produce force	1	1	
			4. Takes off and lands three consecutive times on preferred foot	0	1	
			5. Takes off and lands three consecutive times on nonpreferred foot	0	0	
					Skill Score	7/10
4 Horizontal Jump	A minimum of 10 feet of clear space and tape	Mark off a starting line on the floor. Have the child start behind the line. Tell the child to jump as far as he or she can. Repeat a second trial.	1. Preparatory movement includes flexion of both knees with arms extended behind body	1	1	
			2. Arms extend forcefully forward and upward reaching full extension above the head	0	1	
			3. Take off and land on both feet simultaneously	1	1	
			4. Arms are thrust downward during landing	0	0	
					Skill Score	5/8
5 Slide	A minimum of 25 feet of clear space, a straight line, and two cones	Place the cones 25 feet apart on top of a line on the floor. Tell the child to slide from one cone to the other and back. Repeat a second trial.	1. Body turned sideways so shoulders are aligned with the line on the floor	1	1	
			2. A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot	0	1	
			3. A minimum of four continuous step–slide cycles to the right	1	1	
			4. A minimum of four continuous step–slide cycles to the left	0	0	
					Skill Score	5/8

25/40

CHILD 12. POSTTEST



Post-test

Child: 12

1. Run	60 feet of clear space, and two cones	Place two cones 50 feet apart. Make sure there is at least 8 to 10 feet of space beyond the second cone for a safe stopping distance. Tell the child to run as fast as he or she can from one cone to the other when you say "Go." Repeat a second trial.	1. Arms move in opposition to legs, elbows bent	1	1	
			2. Brief period where both feet are off the ground	1	1	
			3. Narrow foot placement landing on heel or toe (i.e., not flat footed)	0	1	
			4. Nonsupport leg bent approximately 90 degrees (i.e., close to buttocks)	1	1	
					Skill Score	7/8
2.Skip	25 feet of clear space and two cones	Tell the child to skip from one cone to the other. Repeat a second trial by skipping back to the original cone	1.Rhythmic pattern of step hop on alternating feet	0	0	
			2.Foot of non-support leg carried low to the ground	1	1	
			3.Arms move bilaterally in opposition to the legs	1	1	4/6
3. Hop	A minimum of 15 feet of clear space	Tell the child to hop three times on his or her preferred foot (established before testing) and then three times on the other foot. Repeat a second trial.	1. Nonsupport leg swings forward in pendular fashion to produce force	1	1	
			2. Foot of nonsupport leg remains behind body	1	1	
			3. Arms flexed and swing forward to produce force	1	1	
			4. Takes off and lands three consecutive times on preferred foot	1	1	
			5. Takes off and lands three consecutive times on nonpreferred foot	0	1	
					Skill Score	9/10

Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
4 Horizontal Jump	A minimum of 10 feet of clear space and tape	Mark off a starting line on the floor. Have the child start behind the line. Tell the child to jump as far as he or she can. Repeat a second trial.	1. Preparatory movement includes flexion of both knees with arms extended behind body	1	1	
			2. Arms extend forcefully forward and upward reaching full extension above the head	1	1	
			3. Take off and land on both feet simultaneously	1	1	
			4. Arms are thrust downward during landing	0	0	
					Skill Score	6/8
5 Slide	A minimum of 25 feet of clear space, a straight line, and two cones	Place the cones 25 feet apart on top of a line on the floor. Tell the child to slide from one cone to the other and back. Repeat a second trial.	1. Body turned sideways so shoulders are aligned with the line on the floor	1	1	
			2. A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot	1	1	
			3. A minimum of four continuous step–slide cycles to the right	1	1	
			4. A minimum of four continuous step–slide cycles to the left	1	1	
					Skill Score	8/8

~~4~~ 34/40